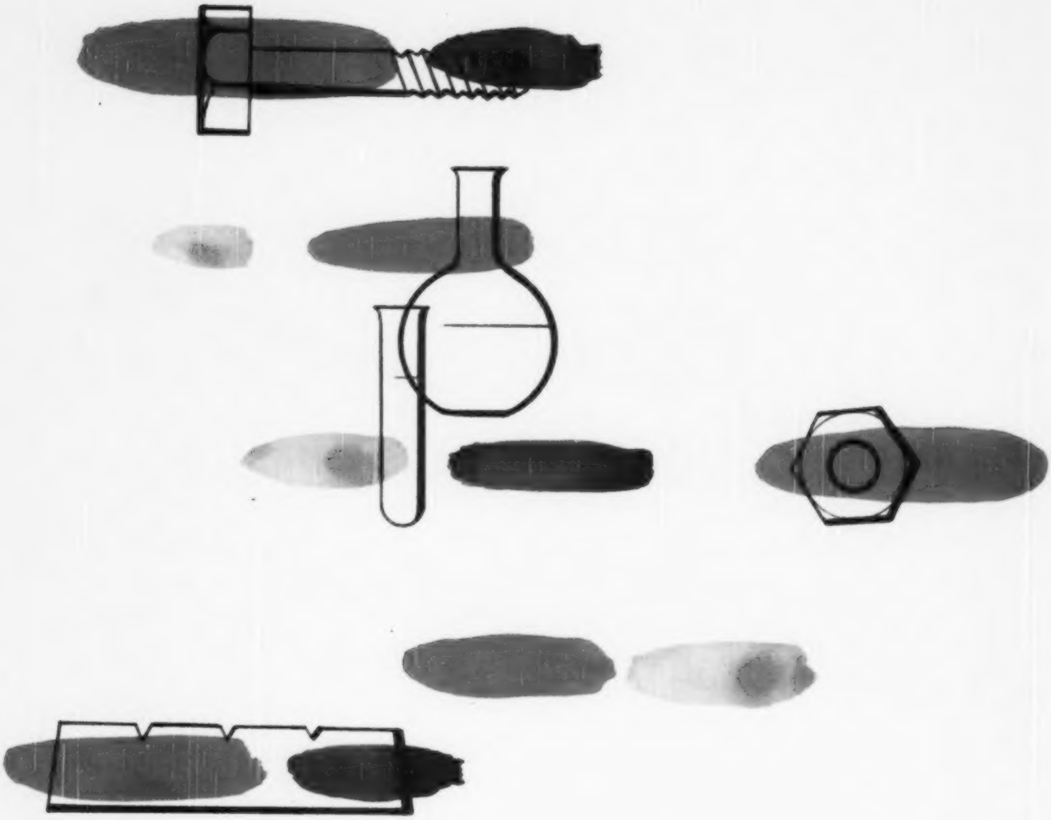


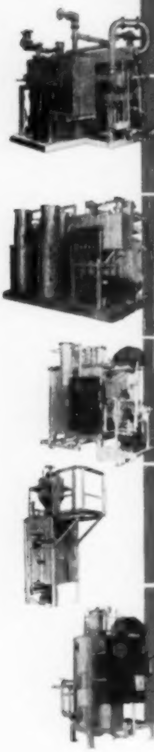
METAL PROGRESS

FEBRUARY 1950

'Surface' PREPARED

Gas Atmospheres

...for every heat treatment of ferrous and non-ferrous metals



TYPE OF GAS	* SIZES OF AVAILABLE UNITS	METAL TO BE TREATED				
		COPPER	LOW C. STEEL UP TO 0.20 C	MED. C. STEEL 0.20-0.60 C	HIGH C. STEEL ABOVE 0.60	SPECIAL STEELS
DX GAS (LEAN) 40° F. DEW POINT	250 TO 35,000 CU. FT. PER HOUR	BRIGHT ANNEAL	———	———	———	———
DX GAS (RICH) 40° F. DEW POINT	250 TO 35,000 CU. FT. PER HOUR	———	BRIGHT ANNEAL	UP TO 30 MIN. EXPOSURE BRIGHT ANNEAL AND CLEAN HARDEN	———	———
NX GAS	1,000 TO 20,000 CU. FT. PER HOUR	BRIGHT ANNEAL	BRIGHT ANNEAL	BRIGHT ANNEAL CLEAN HARDEN	BRIGHT ANNEAL CLEAN HARDEN	———
RX GAS	250 TO 3,500 CU. FT. PER HOUR	Oxygen, O_2, is the only one of the common gases which reacts with copper, consequently, the atmosphere generator may be dispensed with in the bright annealing of that metal. It is only necessary to set the furnace burners slightly rich to prevent free oxygen within the furnace.	CARBURIZE DRY CYANIDING	CARBURIZE BRIGHT ANNEAL CLEAN HARDEN CARBON RESTORATION (SKIN RECOVERY) DRY CYANIDING	BRIGHT ANNEAL CLEAN HARDEN	———
CHAR-MO GAS	500 TO 1,000 CU. FT. PER HOUR		CARBURIZE	CARBURIZE BRIGHT ANNEAL CLEAN HARDEN	BRIGHT ANNEAL CLEAN HARDEN	CLEAN HARDEN TUNGSTEN MOLYBDENUM STEEL
AX GAS (DISSOCIATED AMMONIA)	500 TO 4,000 CU. FT. PER HOUR		———	———	———	BRIGHT ANNEAL STAINLESS STEEL

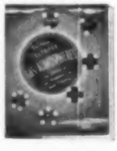
* Where larger capacities are required multiple units can be supplied.

● Surface Combustion research in the development and use of specially prepared gas atmospheres for all heat treatments of ferrous and non-ferrous metals has made possible metallurgical results of such significance that it goes beyond the mechanical details of furnace construction.

Today, with the use of 'Surface' indirectly heated furnaces—radiant tube heating elements and muffle type units and 'Surface' Prepared Gas Atmospheres, all metal surfaces can be treated to prevent undesirable effects or to produce surface conditions as required.

FOR PREPARED GAS ATMOSPHERE COMPOSITIONS, COSTS, AND DETAILS OF APPLICATIONS

write for booklet, "The Science of Gas Chemistry for Heat Treating" Form SC-129.



SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO

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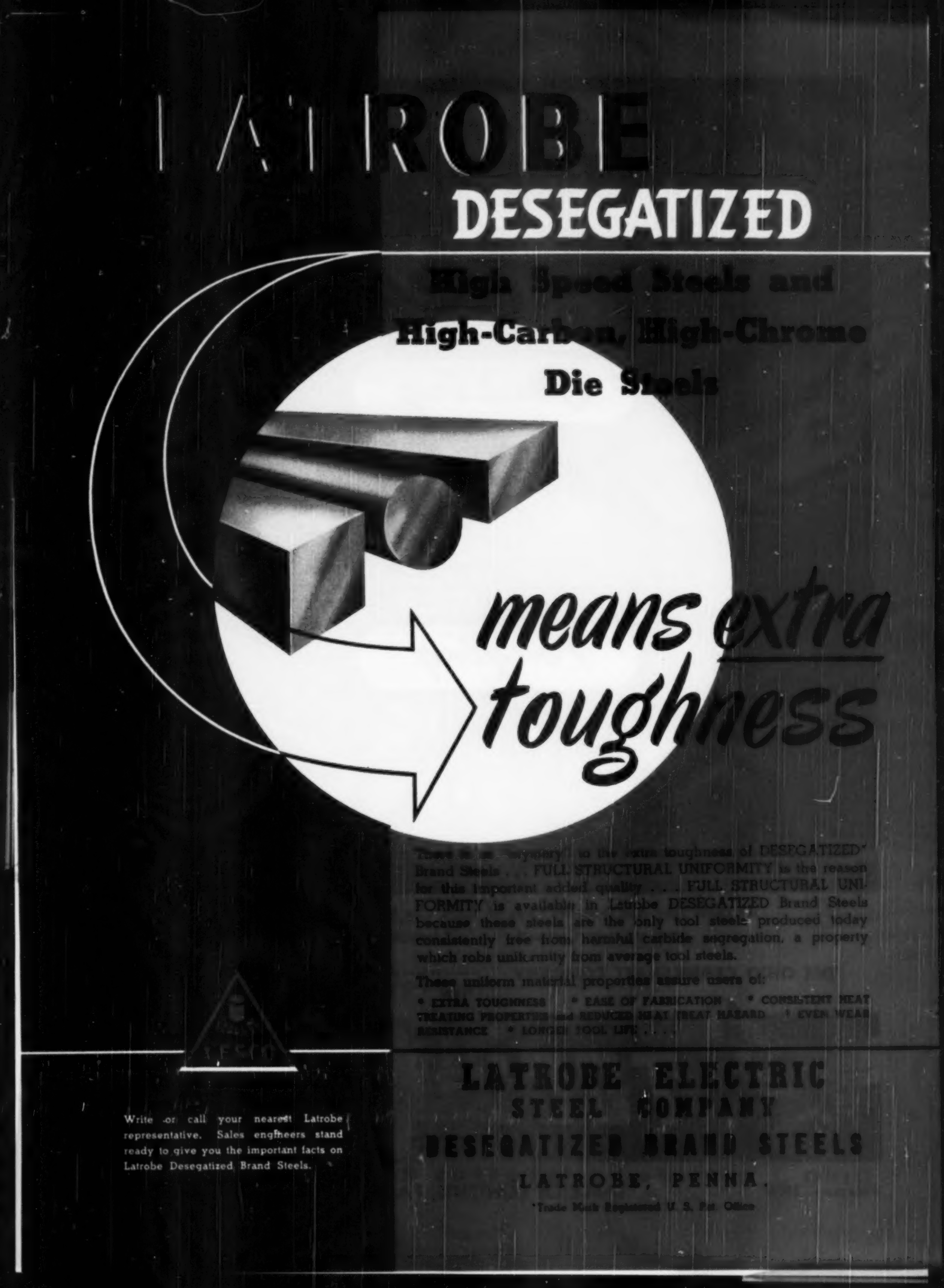
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DESEGATIZED
High Speed Steels and
High-Carbon, High-Chrome
Die Steels
means extra
toughness
There is no "mystery" to the extra toughness of DESEGATIZED* Brand Steels . . . FULL STRUCTURAL UNIFORMITY is the reason for this important added quality . . . FULL STRUCTURAL UNIFORMITY is available in Latrobe DESEGATIZED Brand Steels because these steels are the only tool steels produced today consistently free from harmful carbide segregation, a property which robs uniformity from average tool steels.
These uniform material properties assure users of:
• EXTRA TOUGHNESS • EASE OF FABRICATION • CONSISTENT HEAT TREATING PROPERTIES and REDUCED HEAT TREAT HAZARD • EVEN WEAR RESISTANCE • LONGER TOOL LIFE . . . .
Write or call your nearest Latrobe representative. Sales engineers stand ready to give you the important facts on Latrobe Desegatized Brand Steels.
LATROBE ELECTRIC STEEL COMPANY
DESEGATIZED BRAND STEELS
LATROBE, PENNA.
*Trade Mark Registered U. S. Pat. Office

*W*hen detecting temperature by radiation method . . .

Quick-sighting optical system **lets user select desired target easily, and then check the sharply-defined area which the Rayotube sees. Increased sharpness is also of benefit when radiation comes from end of a closed tube.**

Hermetically sealed construction **at lens, window, and leadwires keeps out dust and gases. New design guards inherent accuracy and stability, even with high or rapidly changing Rayotube housing temperatures.**

Which do you want?

If you already know about Rayotubes, we'll send you brief material to bring you up-to-date on the new model. If you want the full story on all Rayotubes, ask for Cat. N-33B. Please specify. Write Leeds & Northrup Company, 4927 Stenton Ave., Phila. 44, Pa.

Built to work with all Micromax and Speedomax Rayotube instruments, this new Rayotube is an important advance in radiation pyrometry. Present users of Rayotubes, as well as future ones, will find this completely new, advanced design detector unusually easy to apply, especially to such equipment as slab furnaces, soaking pits, open-hearths, ceramic kilns . . . whereever operating conditions are severe.

Purposely designed for easy, low cost replacement, the new Rayotube fits all existing Rayotube mountings. This unit requires no protection against high ambient temperature unless its housing temperature exceeds the very high figure of 350 F. Below that point, any previously installed water- or air-cooling can simply be turned off or disconnected.

Temperature control engineers will welcome these and many other new concepts of design built into this highly versatile temperature detector.

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LN LEEDS & NORTHRUP CO.

Jrl. Ad NS3(1)

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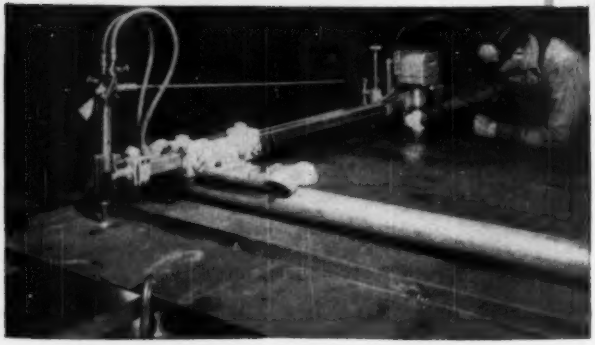
"We can't say enough about Airco's NEW No. 3 Monograph...



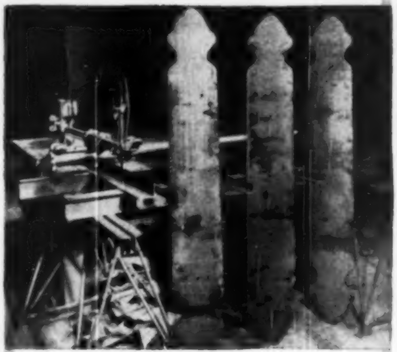
its portability, accuracy and shape cutting versatility make it a MUST for every metal working shop..."

Says Mr. J. C. Hustad, President
Hustad Company, Minneapolis, Minn.

Used for machine gas cutting of special structural shapes at Hustad, the Airco No. 3 Monograph has more than proved its ability to meet the demand for straight line, circle and bevel cutting, with an extremely high degree of accuracy.

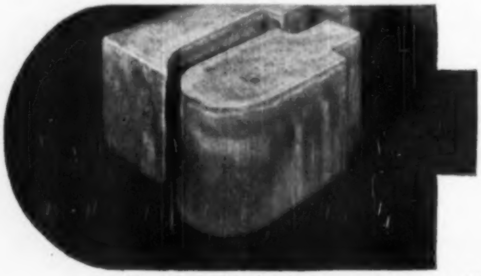
Further, with a cutting area of 32 inches by 56 inches, it gives excellent results in cutting most any steel shape up to 8 inches thick . . . and a 6-foot 8-inch rail can be added, extending the cutting area indefinitely.

This NEW machine is the lowest priced machine of its type in the field (only $695, including a manual tracing device, torch, tip, tubular rail, hose and carrying case). Also, it is portable—the machine itself weighs but 110 lbs. and the tubular rail 35 lbs. The entire unit is packed in a carrying case which can be conveniently handled by two men.



SPECIAL TRIAL OFFER
(Good in Continental U.S.A. Only)

If you would like to try this machine for two weeks *in your own shop on your own work*, just drop a letter to your nearest Airco office or authorized Airco dealer and they will advise you how a shop-trial can be arranged . . . or, if you would like a descriptive folder (ADC-660) they will be glad to send you a copy.



This shows a clevis for a steel mill guide cut from 6" plate—note the smoothness of the cut, reducing considerably machining cost and time.

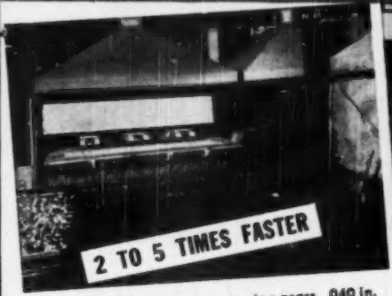
AIRCO AIR REDUCTION
Offices in Principal Cities

Headquarters for Oxygen, Acetylene and Other Gases . . . Calcium Carbide
Gas Cutting Machines . . . Gas Welding and Cutting Apparatus and Supplies . . . Arc Welders, Electrodes and Accessories.

AJAX ELECTRIC SALT BATH FURNACES

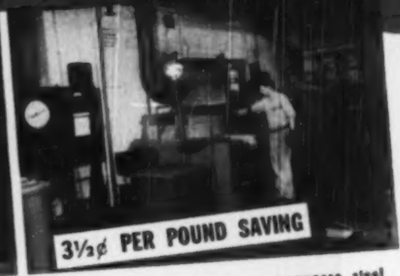
HULTGREN

offer proved advantages like these . . .



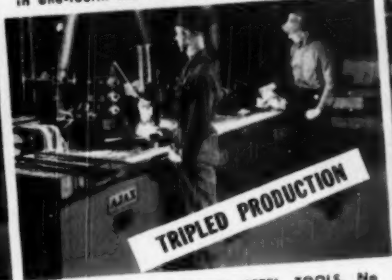
CARBURIZING automobile steering gears. .040 in. case in 2½ hours from 2 to 5 times faster than other carburizing methods.

PROCESS ANNEALING medium carbon alloy steel wire. 1200 pound charge annealed in 45 minutes compared with 12 hours previously required and in one-fourth the floor space.



NEUTRAL HARDENING silicon-manganese steel gears without decarburization. Direct savings 3½c per pound of work treated.

MARTEMPERING ball bearing races in mechanized unit eliminated 5 workers; reduced rejects from 12% to 0%. Distortion reduced from .003 in. to .001 in., eliminating need of die quenching.



HARDENING HIGH SPEED STEEL TOOLS. No decarburization or surface imperfections. Production increased 3 times over old method.

CYANIDE HARDENING ends of automotive valve pusher rods in 2 mechanized furnace lines reduced labor costs 80%.

Ajax Electric Salt Bath Furnaces are available in a complete range of sizes and types for:

CARBURIZING
CYANIDE HARDENING
NEUTRAL HARDENING
ANNEALING or HARDENING
STAINLESS STEEL
BRAZING
HARDENING HIGH SPEED STEEL
AUSTEMPERING
MARTEMPERING
PROCESS ANNEALING
CYCLIC ANNEALING
SOLUTION HEAT TREATMENT
DRAWING (TEMPERING)
DESCALING
CLEANING
DESANDING

. . . ON 4 HEAT TREATING APPLICATIONS OUT OF 5

Ajax Electric Salt Bath Furnaces offer tremendous advantages over conventional heat treating methods *in almost every case.* This fact is proved beyond question in well over 2,500 installations ranging from small batch type units to huge mechanized furnaces. And, by way of further proof, Ajax will gladly treat a job batch of your materials *under actual shop conditions* in the Ajax Metallurgical Laboratory. Thus you see exactly what results will be obtained, under what labor conditions and at what cost, before you buy.

Get your name on the list to receive TIPS AND TRENDS, the Ajax periodical that will keep you up to date on salt bath heat treating methods and developments. Each issue is chock-full of practical heat treating "know how" written by specialists. Available on request.

AJAX ELECTRIC COMPANY, Inc., 910 Frankford Avenue, Philadelphia 23, Pa.

THE WORLD'S LARGEST MANUFACTURER OF ELECTRIC HEAT TREATING FURNACES EXCLUSIVELY

In Canada: Canadian General Electric Co., Ltd., Toronto, Ont.

Associate Companies: Ajax Metal Co., Ajax Electric Furnace Corp., Ajax Electrothermic Corp., Ajax Engineering Corp.

HIGHER PRODUCTION? *Yes!*

LOWER COSTS? *Yes!* — and ACCURACY BESIDES

with the MOTCH & MERRYWEATHER NO. 2-A CIRCULAR SAWING MACHINE

As with all Motch & Merryweather Circular Sawing Machines, the No. 2-A (automatic) brings you all the advantages of the Triple-Chip Method. Stock up to 6" is sawed accurately to length without burrs, giving a mill-type finish, which eliminates second operations. Work is held rigidly on both sides of the blade. With the M. & M. Triple-Chip Saw Blade, correctly sharpened by the No. 1 Automatic Grinder, maximum cut-off speed and accuracy are attained. *Ask us to furnish you with cutting time figures.*

* * *

Triple-Chip METHOD

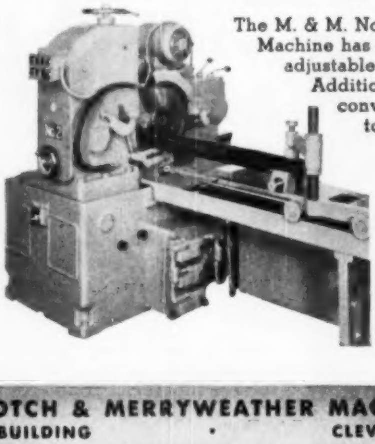
1¢ PER CUT

Triple-Chip Method cut off 490 pieces in 50 seconds per cut at a cost of \$.0101 per piece.

TRIPLE-CHIP vs. ALTERNATE METHOD (Sawing SAE 1020 5" O. D.)

$3\frac{1}{4}$¢ PER CUT

Alternate method cut off 100 pieces in 235 seconds per cut at a cost of \$.0325 per piece.



The M. & M. No. 2-A Circular Sawing Machine has automatic, micrometer adjustable-stop bar feed to 36". Additional stroke lengths and conveyor can be furnished to accommodate long length bars.

• • •

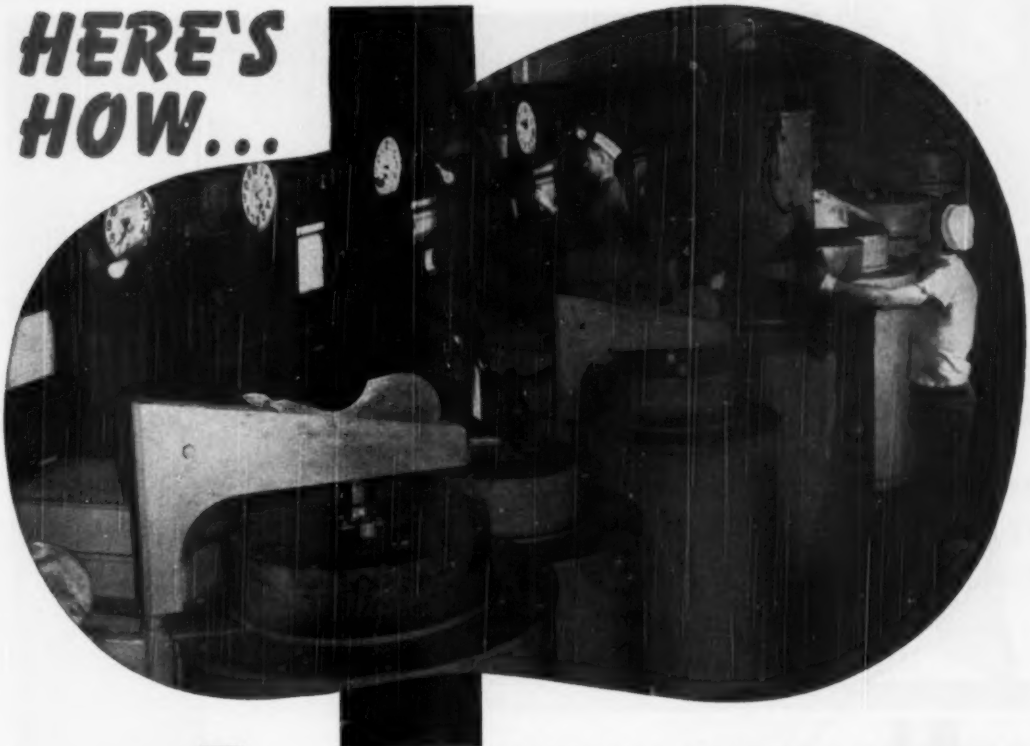
A complete range of circular sawing machines is available for stock up to 16½" round as well as special machines to meet your requirements.

Write on your letterhead for Bulletin No. 2-MP.

THE MOTCH & MERRYWEATHER MACHINERY CO.
PENTON BUILDING • CLEVELAND 13, OHIO

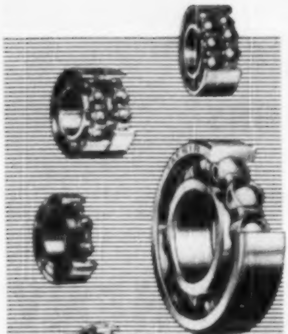
AT YOUR COMMAND • AN UNPARALLELED EXPERIENCE IN CIRCULAR SAWING

HERE'S HOW...



FAFNIR USES 20 LINDBERG CYCLONES

...to draw thousands of types of bearings!



The Fafnir Bearing Company, New Britain, Conn., uses Lindberg Cyclone Furnaces to draw thousands of types and sizes of its line of ball bearings. They say:

"The metallurgical department of our company entrusts the major part of its drawing operations to Lindberg Cyclone Furnaces because it has found them to be dependable work horses. At the present time there are 20 in use in the Company's three ball bearing plants in New Britain, Conn.

"They have given excellent continuous service for more than 8 years. For long periods they were operated 24 hours a day, seven days a week, (at temperatures ranging from 275 to 1200°F.) without downtime due to furnace failure.

"Because the Fafnir line of ball bearings,comprising thousands of types and sizes, is considered the most complete manufactured in this country, the Lindberg Cyclones draw a considerable variety of parts. The work varies from small to large dense loads (up to 1600 lbs.) of bearing rings, balls and rolls, yet the uniform results demanded for the manufacture of precision products is constantly being achieved—and in an atmosphere of cleanliness and satisfactory working conditions."

Local Offices in every industrial center.

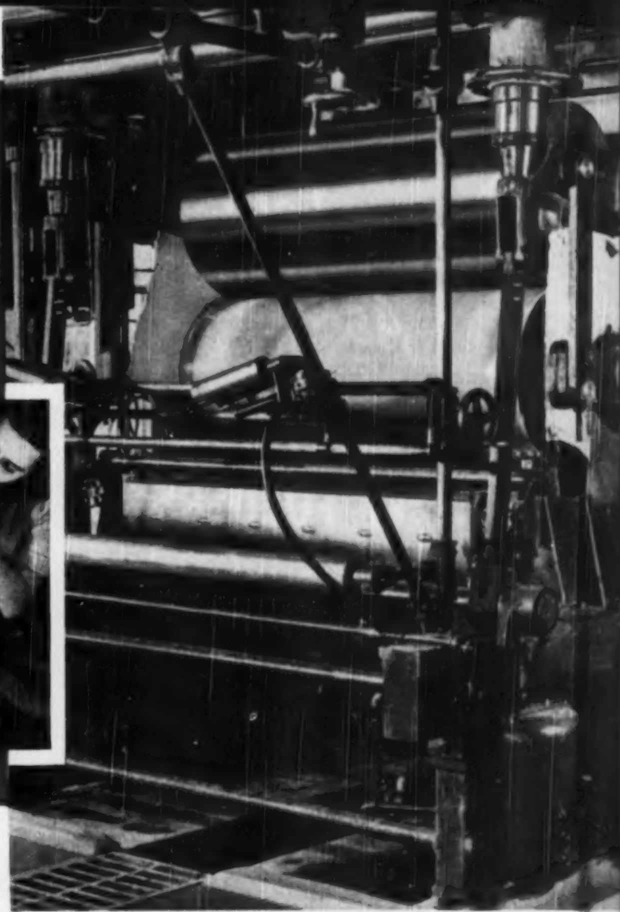
LINDBERG ENGINEERING COMPANY 2448 W. Hubbard Street, Chicago 12, Illinois.

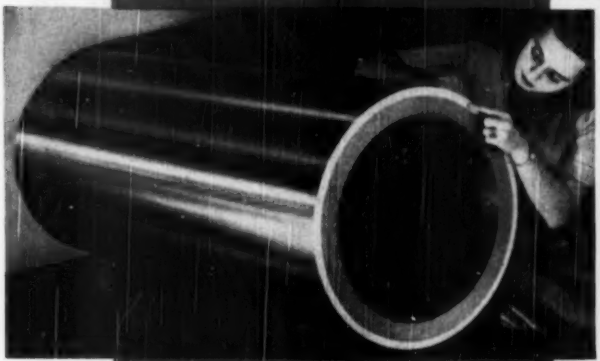
LINDBERG FURNACES

Award for top furnace performance... INTERNATIONAL ELECTRODES

Announcing
a new design
in laboratory
GLOBAR
FURNACES
the third presentation of
a New Furnace Design by
HEVI DUTY
temperature range from 2000°F to 2600°F
This Hevi Duty electric furnace is designed for operation at high temperature with or without a protective atmosphere. Heating elements are "Globar" type rods extending across the chamber, above and below the refractory muffle. The design incorporates the most recent developments introduced by Hevi Duty engineers.
Write for complete details or see your laboratory Supply Dealer.
Instruments and Controls Operate at Approximately Room Temperature
NEW
OLD
Improved Insulation Design with Minimum of Radiation Loss
48 Steps of Control Through a Hevi Duty Tap-Changing Transformer
Instruments Easily Accessible Through Removable Panels
HEVI DUTY ELECTRIC COMPANY
HEAT TREATING FURNACES
HEVI DUTY
ELECTRIC EXCLUSIVELY
DRY TYPE TRANSFORMERS — CONSTANT CURRENT REGULATORS
MILWAUKEE 1, WISCONSIN

DUAL METAL DOES IT AGAIN!





TWO METALS ARE BETTER THAN ONE—Dual Metal textile roll... stainless steel outside, metallurgically bonded to a gray iron core, rough machined and ready for shipment from our plant.

ONE ROLL WITH A DOUBLE ROLE! This three-roll heavy duty padder made by the Morrison Machine Company with the dual metal rolls top and bottom and rubber-covered iron roll in the middle is used by the textile industry to impregnate and squeeze many fabrics.

Take, for example, the casting of the rolls we make for the Morrison Machine Company of Paterson, New Jersey, one of America's leading designers and builders of textile machinery.

Two metallurgical characteristics are needed—an outer shell that resists corrosion from bleaches, finishes and dyes, *plus* an inner core that makes for economy and ease in fabricating.

No *one* metal can do both economically. So utilizing centrifugal force and temperature, the two dissimilar metals are poured successively in horizontally spinning metal molds. The casting thus has an outer shell of stainless steel metallurgically bonded to an inner core of gray iron.

Result? A vastly superior roll . . . *one* that combines *two* metallurgical properties into a single structural unit and makes possible a heavier, more rigid roll at lower cost!

Today we are supplying single and dual metal cylindrically shaped castings to an ever increasing list of progressive equipment builders.

Centrifugal castings may be the answer to *your* problem. In any case, why not find out? Write today and tell us what you're up against. We may be able to help.

TYPES OF METAL CAST

Stainless Steel—all AISI Types, plus special heat and corrosion resistant analyses.

Alloy Steel—all grades.

Carbon Steel—all grades.

Gray and Alloy Iron — all standard and special analyses, including Ni-Hard and Ni-Resist.

Dual Metal—gray or alloy iron inside steel; gray iron inside chilled iron, tool steel, or Ni-Hard; iron or steel inside stainless; and many other metallurgically bonded two-metal centrifugally cast combinations.

SIZE RANGE

Outside Diameters—2½" through 53". Wall Thickness—⅜" to 4". Lengths—Up to 10'.

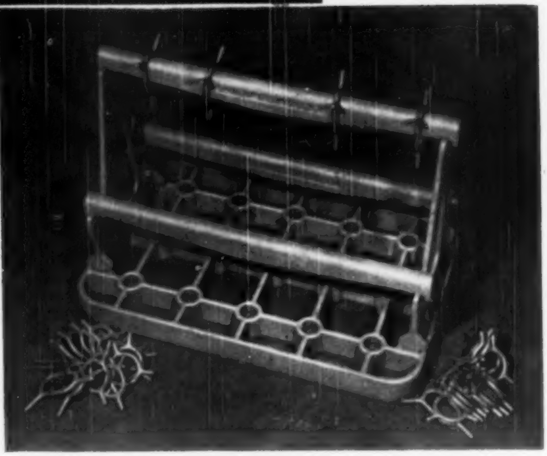
U. S. PIPE AND FOUNDRY CO.

SPECIAL PRODUCTS DIVISION — **BURLINGTON, NEW JERSEY**

SPECIAL PRODUCTS DIVISION

AMERICA'S LARGEST PRODUCER OF CENTRIFUGALLY CAST FERROUS METAL PRODUCTS IN TUBULAR FORM

GAS CARBURIZING TRAYS



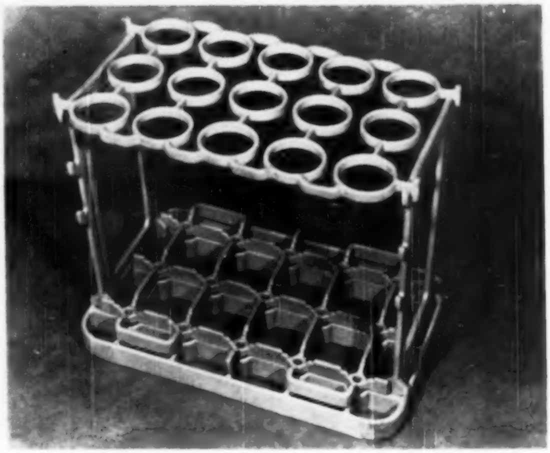
Job-proven in Industry!

The design of gas carburizing trays and fixtures to obtain maximum service life requires a thorough knowledge and understanding of

- the effect of temperature differentials of each application.
- effect of black body conditions of each specific loading.
- effect of square corners and small radii.
- effect of unequal sections.
- effect of cooling rates in the mold, the furnace, and the quench tank.
- plus a complete knowledge of foundry techniques to obtain the highest quality castings.

Hundreds of trays are being used by industries with unnecessary designed-in self-fatiguing stresses which are costing the consumer thousands of dollars per year through decreased service life.

If you are interested in lower heat-hour costs, call an **ACCOLOY ENGINEER** for an honest analysis of your problem. There is no obligation on your part.



WE MAKE: MUFFLES · RETORTS · BELTS · CHAIN
ROLLER RAILS · CARBURIZING BOXES · SALT POTS

ALLOY *ENGINEERING* & CASTING COMPANY

ALLOY CASTING CO. (DIVISION)
CHAMPAIGN, ILLINOIS

HEAT RESISTANT CASTINGS
ACCOLOY
STAINLESS STEEL CASTINGS

ENGINEERS AND PRODUCERS OF HEAT AND CORROSION RESISTANT CASTINGS

4 Steps to Increased Tool Life

1. Design each tool carefully to perform its job, considering *fully* all known factors which influence tool life.

2. Select tool steel of the correct chemical analysis with the best combination of properties for each tool or die.

3. Follow heat-treatment recommendations exactly. Use lots of care in hardening and tempering. Avoid excessive decarburization.

4. Establish grinding techniques that produce the ideal surface finish for the intended service, free from grinding cracks.

If you have not been following these four steps religiously, do so and you'll increase tool life.

Bethlehem Steel Company, Publications Department
Bethlehem, Pa.

Please send me a copy of your new booklet describing:

- ☐ *Carbon and Carbon-Vanadium Tool Steels*
- ☐ *Hot-Work Tool Steels*
- ☐ *Oil and Air-Hardening Tool Steels*
- ☐ *High-Speed Tool Steels*
- ☐ *Shock-Resisting Tool Steels*
- ☐ *Tool Steel Selector*

(Check the booklets you wish to receive)

Name ______ Title ______
Company ______
Company Address ______
City ______ Zone ______ State ______

It's not a simple formula. Tool design must take many factors into consideration. Grinding procedure, too, is a variable that is seldom easy to perfect.

But follow these four steps, and you're headed for better performance and longer life. And we can help you when it comes to selecting the right tool steel.

Heat-treatment technique is another vital step where one of our technical men can put his finger on the spot that may be causing trouble. All of our tool-steel contact metallurgists are experienced tool hardeners, and they've helped to solve a variety of problems involving tool design and grinding.

Whether it's technical assistance or fine tool steels you need, call on Bethlehem. In our mill depot we carry ample stocks of carbon, oil- and air-hardening grades . . . shock-resisting, hot-work and high-speed steels. Just call the nearest Bethlehem sales office or tool-steel distributor for complete information.

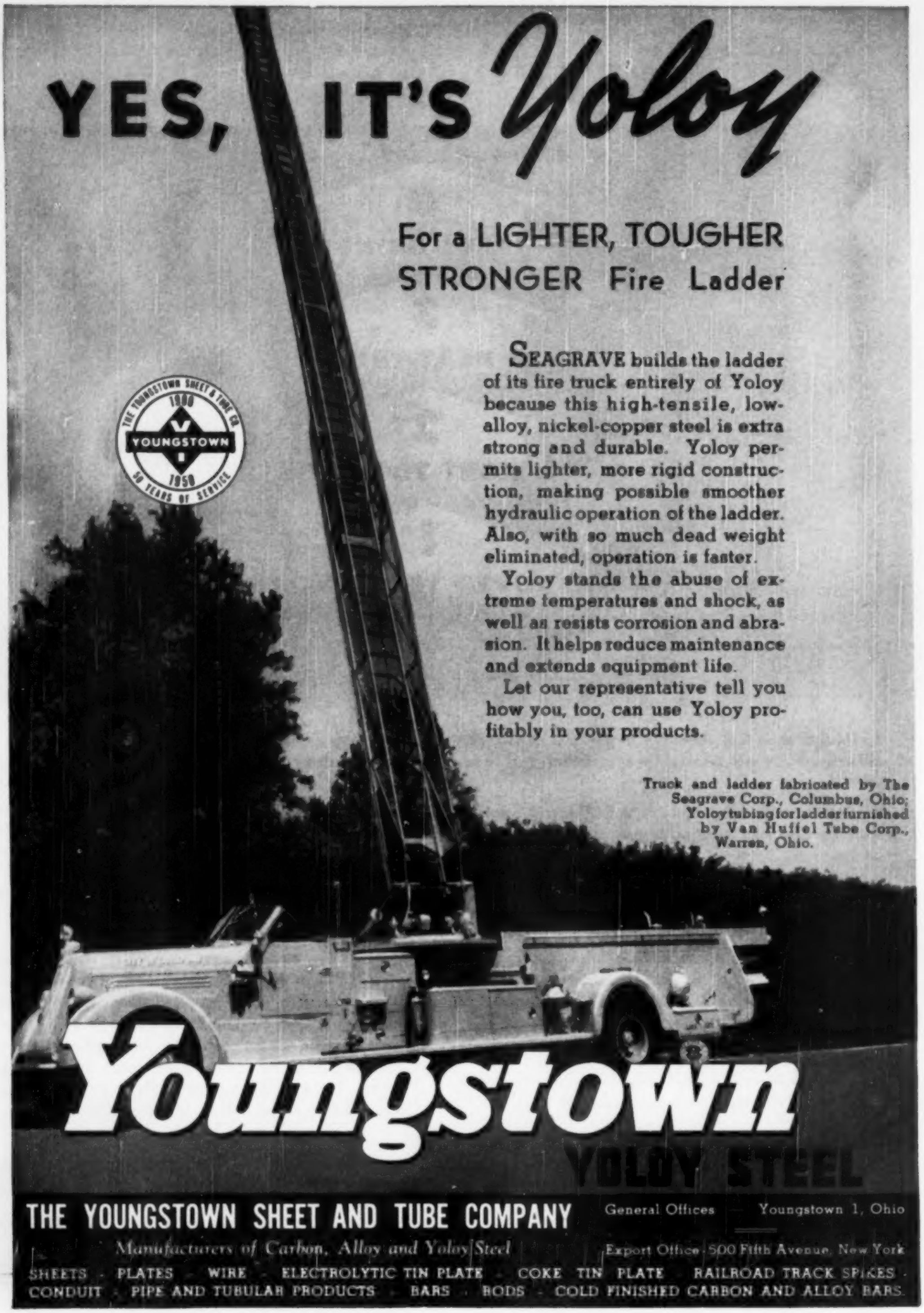
BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by
Bethlehem Pacific Coast Steel Corporation

Export Distributor:
Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM TOOL STEELS for EVERY JOB


YES, IT'S Yoloy
For a LIGHTER, TOUGHER STRONGER Fire Ladder
SEAGRAVE builds the ladder of its fire truck entirely of Yoloy because this high-tensile, low-alloy, nickel-copper steel is extra strong and durable. Yoloy permits lighter, more rigid construction, making possible smoother hydraulic operation of the ladder. Also, with so much dead weight eliminated, operation is faster.
Yoloy stands the abuse of extreme temperatures and shock, as well as resists corrosion and abrasion. It helps reduce maintenance and extends equipment life.
Let our representative tell you how you, too, can use Yoloy profitably in your products.
Truck and ladder fabricated by The Seagrave Corp., Columbus, Ohio; Yoloy tubing for ladder furnished by Van Huffel Tube Corp., Warren, Ohio.
THE YOUNGSTOWN SHEET & TUBE CO. 1900 YOUNGSTOWN 1950 50 YEARS OF SERVICE
Youngstown
YOLOY STEEL
THE YOUNGSTOWN SHEET AND TUBE COMPANY
General Offices — Youngstown 1, Ohio
Manufacturers of Carbon, Alloy and Yoloy Steel
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SHEETS - PLATES - WIRE - ELECTROLYTIC TIN PLATE - COKE TIN PLATE - RAILROAD TRACK SPIKES - CONDUIT - PIPE AND TUBULAR PRODUCTS - BARS - RODS - COLD FINISHED CARBON AND ALLOY BARS

ELECTROMET *Data Sheet*

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Division, Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. • In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario

How SILICOMANGANESE Saves Furnace Time . . . Produces Better, Cleaner Steel

Silicomanganese is used by the steel industry as a furnace block* and deoxidizer, and also for manganese additions.

The cleanness and quality of steel depend largely on how well it has been deoxidized. Deoxidation also greatly influences the physical properties of steel for rolling and subsequent fabrication. Silicomanganese combines two active deoxidizers in a single alloy and it has proved to be a more effective deoxidizer than silicon or manganese alloys added separately. This combination alloy contains silicon and manganese in the correct proportion (approximately 1 to 3.5) to be most effective in reducing the oxygen content of the bath to a low level. The use of silicomanganese produces cleaner steel, saves furnace time, and gives high alloy recovery for manganese additions.

Gets More Oxygen Out of Bath

When silicomanganese is used for blocking and deoxidation, the combined effect of silicon and manganese lowers the oxygen content to a greater degree than silicon alone. This is due to the fact that the amount of oxygen in equilibrium with a given amount of silicon is lower in iron-silicon-manganese alloys than it is in plain iron-silicon alloys, as shown in Fig. 1.

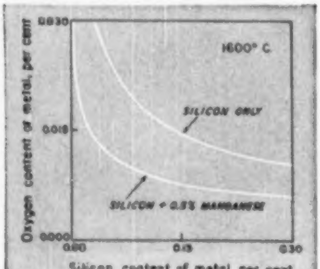

Fig. 1. Limit of solubility of oxygen in iron-silicon alloys, plain and with 0.50 per cent manganese at 1600°C.

*The initial deoxidation of steel, frequently referred to as the furnace block, stops the carbon-oxygen reaction in the furnace. This arrests the carbon drop immediately and makes it possible to secure close control of analysis. If the oxygen content of the metal is reduced well below the level established by the carbon-oxygen reaction, initial deoxidation is accomplished.

Less Inclusions, Cleaner Steel

In addition to lowering the oxygen content, silicomanganese has a specifically beneficial effect on inclusions. The inclusions in a steel depend in large part on how low the carbon content (or how high the oxygen content) is before blocking. The lower the carbon, the dirtier the final steel, almost regardless of the subsequent deoxidation treatment. Since silicomanganese has a low carbon content, it is not necessary to drive the carbon as low (or make the oxygen as high), as when high-carbon or standard ferromanganese is used, so that the final steel is cleaner and has better working properties. The improved cleanliness resulting from silicomanganese is usually noticeable in higher carbon steels, but is outstanding in steels below 0.25 per cent carbon where inclusions and surface defects are a vital problem and where the time saved by blocking at a higher carbon level is significant.

Fast Solubility In Bath

Because of the high concentration of active elements in silicomanganese, less time is required to effect solution of this alloy than when equivalent amounts of silicon and manganese are used separately in the form of ferrosilicon and ferromanganese.

For example, compare these typical analyses of silicomanganese, standard ferromanganese, and 50 per cent ferrosilicon:

	Silicomanganese, %	Standard Ferromanganese, %	50% Ferrosilicon, %
Manganese	66.5	80	—
Silicon	19	—	50
Carbon	1.5	7	—
Iron, approx.	13	13	50

From this it can be seen that 1,000 lb. of silicomanganese would contain 190 lb. of silicon and 665 lb. of manganese. These amounts of silicon and manganese would require 380 lb. of 50 per cent ferrosilicon and 830 lb. of standard ferromanganese, or a total of 1,210 lb. Obviously it is easier and faster to dissolve 1,000 lb. of the combination alloy silicomanganese than 1,210 lb. of these separate silicon and manganese alloys.

Lower Carbon Content

Silicomanganese contains less carbon than any combination of ferrosilicon and standard ferromanganese. Therefore, the carbon-oxygen reaction in the bath can be stopped earlier when silicomanganese is used for blocking. Heats can be blocked at higher carbon levels and hence lower oxygen contents, and the amount of deoxidation required is less.

Fig. 2. Charging silicomanganese into an open-hearth furnace.

Saves Furnace Time

Because of the advantages outlined, silicomanganese can save as much as 20 minutes per melt in the production of open-hearth steel. For low-carbon steel, an even greater saving in time can be realized.

For Producing Engineering Steels

Silicomanganese is also used for alloy additions of manganese, particularly in the production of engineering steels containing 0.10 to 0.50 per cent carbon.

When manganese or other oxidizable additions, such as chromium, must be made to the bath, the use of a block provides a higher alloy recovery. Silicomanganese introduces manganese with the silicon and the usual recovery of this manganese will range from 70 to 85 per cent.

Metallurgical Service Available

Ask to have one of our metallurgists call and explain more fully the advantages of silicomanganese as a furnace block and deoxidizer. He will be glad to help you with the use of ELECTROMET silicomanganese. This alloy contains 65 to 68 per cent manganese and is available in maximum 1.50 per cent and 2.00 per cent carbon grades. Both grades are furnished in a lump size of 75 lb. x 2 in. and in a crushed size of 2 in. x down. Write, wire, or phone the nearest ELECTROMET office.

An example of Salmonella Typhosa Bacteria, magnified 30,000X by Electron Microscope.

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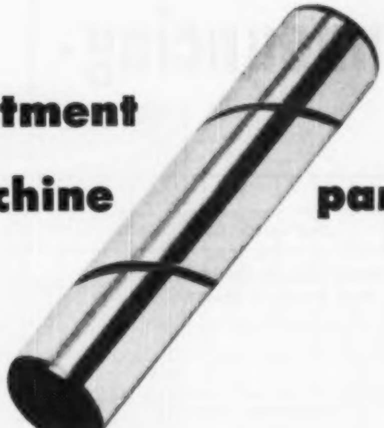

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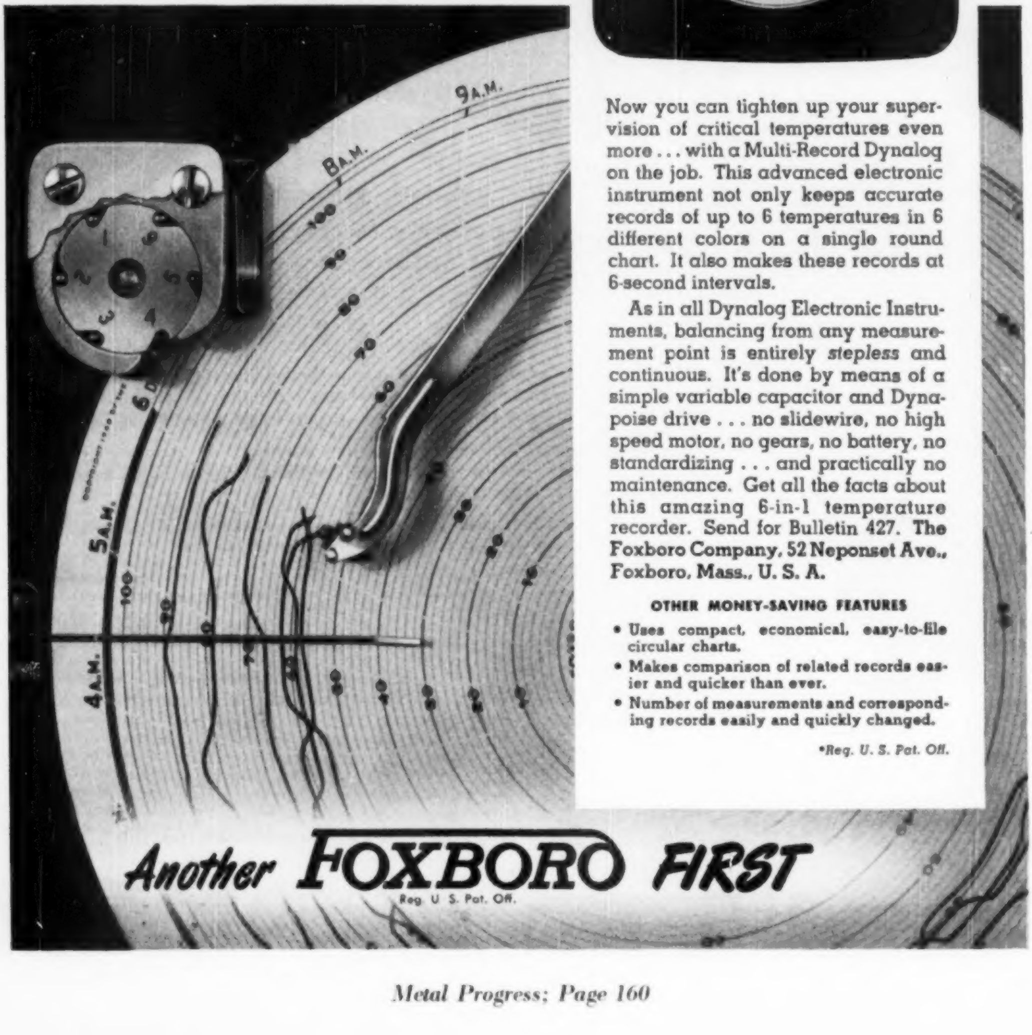

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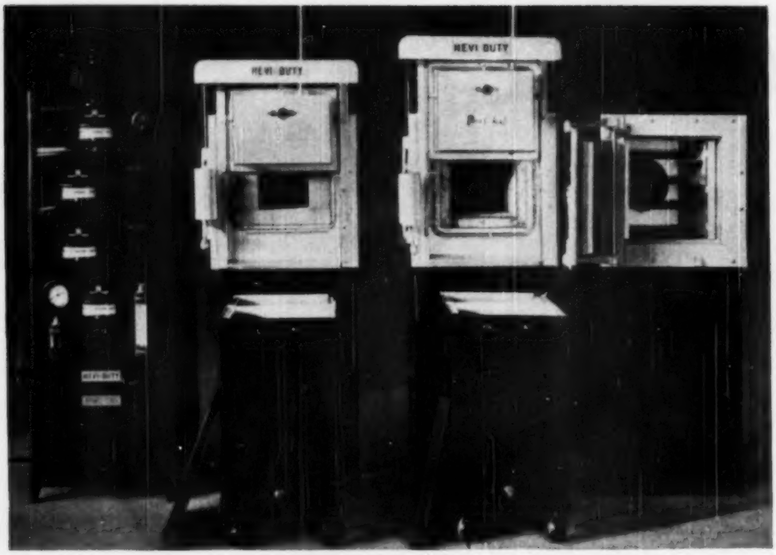

Complete Hevi Duty heat-treating set-up for small parts. Left to right are control panel and Atmo-Gen Generator, HDT-5610-CU Furnace, Treet-All Furnace, and Temperite Furnace. Furnace baffles are made of Inconel.

Built with *INCONEL**...for long life at high temperatures

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For example: In the Hevi Duty Treet-All furnace, the muffle is made of Inconel*. In the Hevi Duty Atmo-Gen Generator, the cracking retort and "hot" connections are made of Inconel.

For high-heat applications such as these, where temperatures may reach 2200° F., Inconel is one of the most durable metals available to present-day designers. Because of its outstanding performance record and excellent cost-to-service ratio, many of the nation's leading fabricators have adopted workable, weldable Inconel as a *standard* metal for high-temperature equipment.

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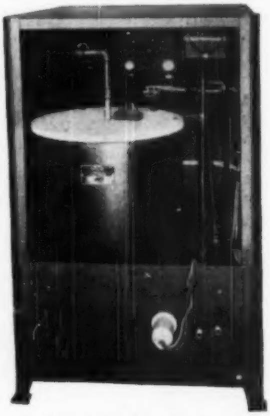

Rear view of Atmo-Gen Generator showing cracking unit and piping. The generator cracks ammonia gas in a heated Inconel retort.

• • •

The equipment shown on this page is manufactured by Hevi Duty Electric Co., Milwaukee 1, Wisconsin.

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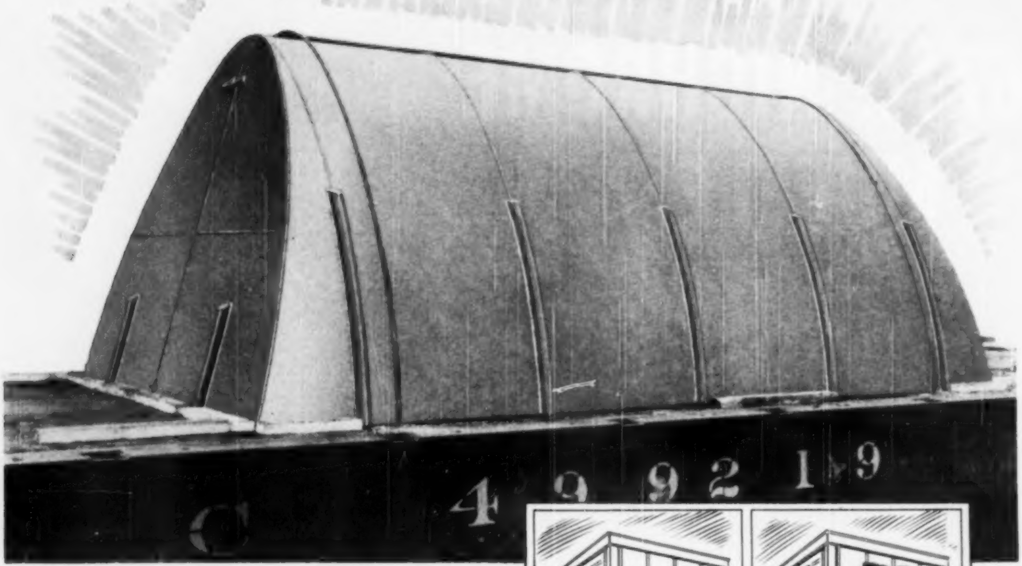

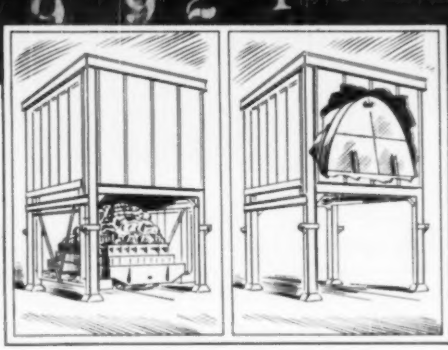

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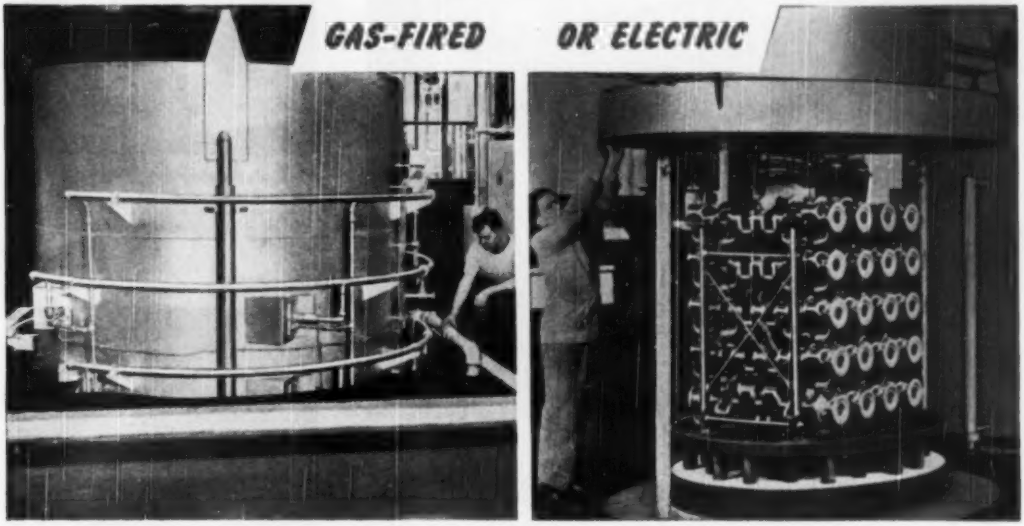

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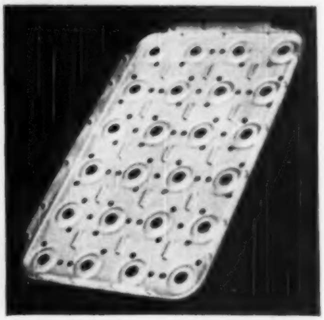
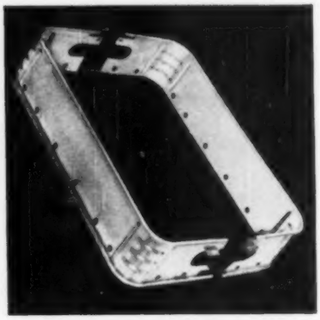


These are the parts of the patented bottle case—produced by modern assembly-line methods: Into a punch press goes a coil of 150S—out comes finished case bottoms.



Two spools of coated steel wire and a coil of 150S are simultaneously fed into a rolling machine to form the body in a completely automatic operation.

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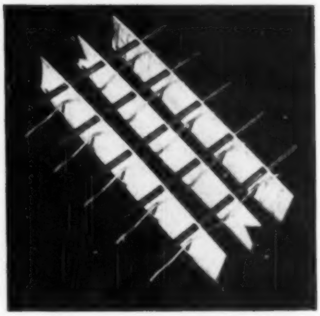

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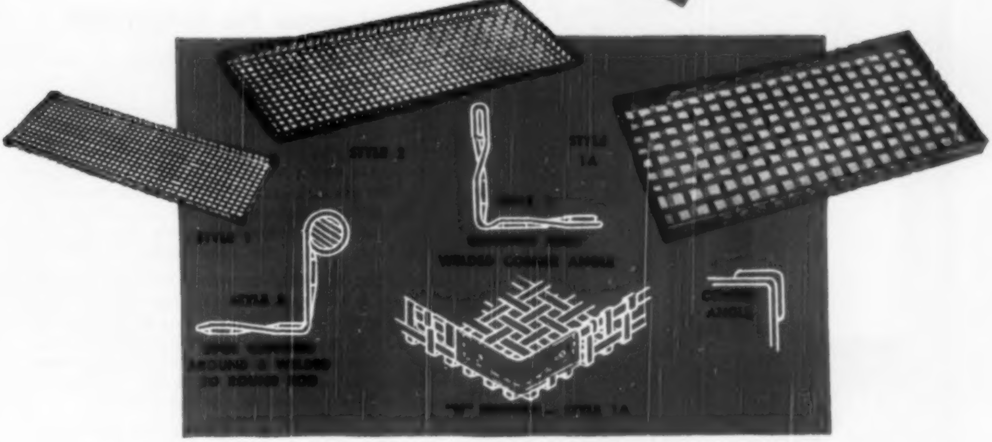

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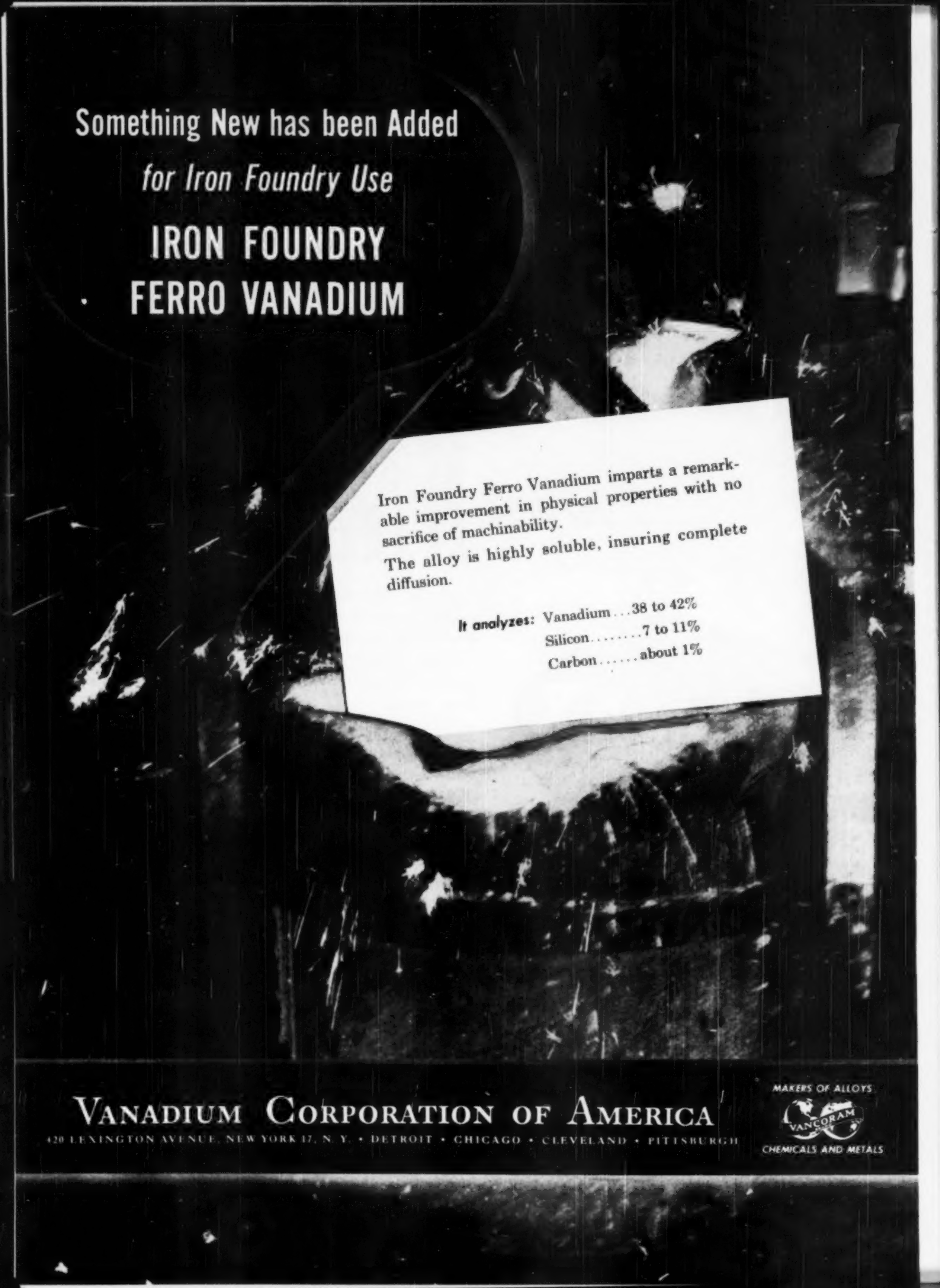
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Metal Progress

The Magazine for Metallurgical Engineers

February 1950

Vol. 57, No. 2

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Some Effects of Quenching and Tempering on Residual Stresses in Steel

By A. L. Boegehold
Head, Metallurgy Department
Research Laboratories Division
General Motors Corp., Detroit

An annual feature of the Detroit ⊕ chapter is its Woodside Lecture. In the most recent of these Past-President Boegehold discussed the general subject of test bar results versus tests on components. Residual stresses get into this comparison as easily as they get into quenched steel. Although tempering is the standard remedy for relieving stresses, it does not necessarily improve the stress pattern. For instance, Mr. Boegehold shows that the surface of a 1-in. round of 4130 was in compression after quenching, but in tension after tempering at 900° F. This article concerns residual stress in cylindrical specimens. A later installment will deal with correlation between test bars and automotive parts.

IN RECENT YEARS much emphasis has been placed on the testing of hardened steels in sizes that will transform to martensite throughout the entire cross section. Such tests are necessary to determine limiting values of the conventional mechanical properties. They are designed to minimize the complicating effects of microstructure; incidentally, they minimize the effects of residual stresses. In small-diameter test bars the hardening reaction is usually completed throughout the bar with so little time lag that the volume increase on hardening takes place quite uniformly throughout the section and only small localized stresses are generated. However, when the same steels are hardened in larger sections, residual stresses are set up as a result of thermal gradients and differing degrees of hardening. The pattern of these residual stresses depends on numerous variables.

The origin of quenching stresses may be reviewed with the aid of Fig. 1, which shows cooling curves for the center and surface of a 1-in. round quenched in oil. In the absence of transformation, length changes are proportional to temperature changes. It is evident, therefore, that after a few seconds of quenching the surface has contracted much more than the center. This causes the surface to stretch and the length to shorten. Since the steel is incompressible, any shortening as a result of the contracting colder envelope will be accompanied by an increased diameter, which also acts to stretch the outer layer. All of this creates, momentarily, a condition of tension in the outer shell and compression in the core.

As cooling continues, the core cools through a much greater temperature range than the outer shell and reverses the transient situation of the first part of the cooling. Thus, the core contracts more than the outer shell and is placed in tension while the outer shell is placed in compression. This is the final result of purely thermal changes during quenching. All metals in which no transformation occurs will behave in a similar manner.

When steel hardens, however, we have a somewhat different situation, depending on the depth to which hardening takes place. At the M_s temperature, shown in the chart at 600° F., austenite begins to transform to martensite. This change in structure is accompanied by a volume increase so that as the temperature continues to decrease from *A* to *C* through the martensite transformation range, the volume or length is no longer proportional to the temperature; contraction is less

than normal, as indicated by the dotted lines in Fig. 1. (The dotted lines are intended to indicate change in length with time and do not refer to the temperature ordinate.) The temperature applicable to any point on the dotted line may be found by constructing a vertical line from the dotted to the solid line and then tracing horizontally over to the temperature scale. At a point on the dotted line directly above the point *C* on the solid line, the volume increase accompanying transformation is complete at the surface and further contraction will again be proportional to temperature; that is, the dotted line resumes parallelism with the solid line. The same sort of volume increase occurs at all points between surface and center in steels that harden throughout the section being quenched.

It will be seen, then, that the volume increase begins near the surface at a time when the subsurface metal is at a much higher temperature and is contracting rapidly. Therefore, the length changes oppose each other during this phase of the cooling. By the time the material near the center of the bar reaches the M_s temperature, the transformation has been completed in the surface layers, and the metal near the surface is attempting to contract against the expanding interior metal. This train of events ends with the metal at the surface in a state of tension.

It should not be assumed from this description that a section hardened to the center will invariably have tensile stress at the surface. Certain sizes that have been drastically quenched, as in water or brine, may arrive at room temperature with compressive stress at the surface of the piece.

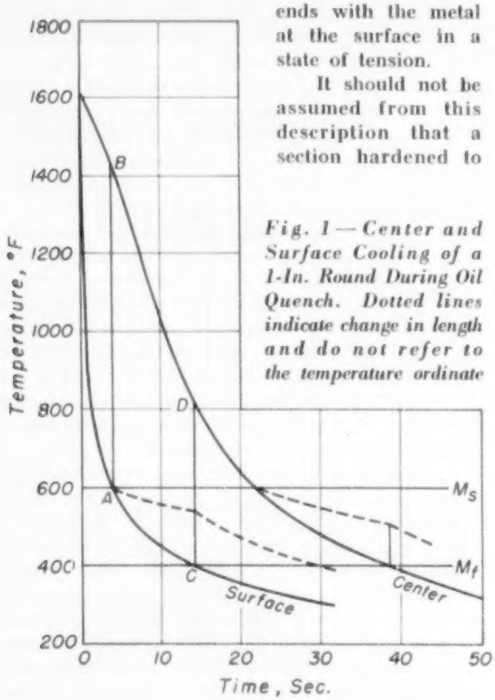


Fig. 1 — Center and Surface Cooling of a 1-In. Round During Oil Quench. Dotted lines indicate change in length and do not refer to the temperature ordinate

The magnitude of the volume changes occurring in the martensite range vary, depending on the carbon content of the steel; deviation of the dotted line from the solid line representing departure of length from temperature proportionality is less for low-carbon steel than for high-carbon steel. In fact, with enough carbon in the steel, the dotted line would actually reverse and show an increase in length with falling temperature. Such an expansion in the interior, occurring while the exterior is contracting, would set up tensile stress great enough to exceed the yield point. In ductile steel the result would be plastic flow and readjustment of stress. In brittle steel the yield and tensile strengths are identical, and cracking would occur. With somewhat less internal expansion resulting from a lower carbon content, the resultant tensile stress in the surface layers may be only slightly less than the yield strength and if the steel were not tempered it would be ready to yield — or, if brittle, to fracture — with only light stress from externally applied loads.

With increased section size or decreased hardenability, a different result ensues due to lack of hardening in some portion of the interior. When the interior does not harden, there is no expansion to stretch the outer shell; therefore, compressive stress is the final state in the outer layers, balanced by tension in the interior. Here again the resultant stress may be almost any amount, depending on the relative amounts of the cross section occupied by hardened and unhardened structures. The highest compressive stress would be slightly less than the yield point. A higher stress would cause plastic flow and, therefore, relief of stress.

Thus it is evident that the surface of a hardened steel object may contain residual stress of any amount between the yield strength in tension and the yield strength in compression.

Effect of Tempering

Although residual stress resulting from hardening has been discussed long ago and repeatedly in metallurgical publications, the effect of tempering has not often been considered. Frequently such consideration gets no further than a statement that tempering progressively decreases residual stresses. Actually, this well-known generalization is not always true. For instance, when retained austenite is decomposed during tempering, the resulting

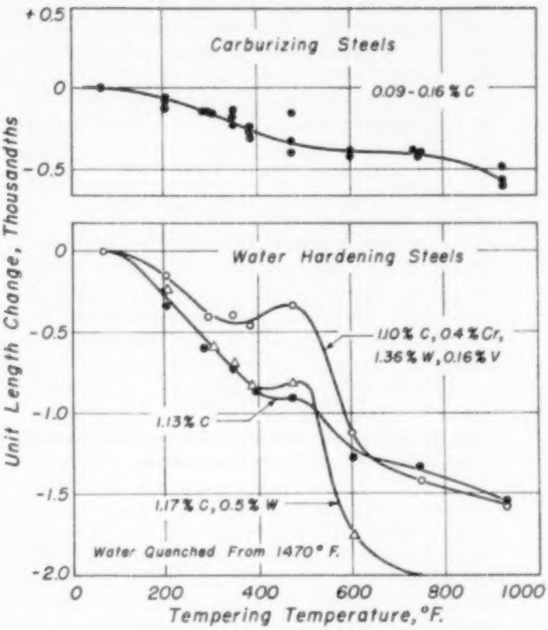


Fig. 2 — Length Changes During Tempering. (H. Scott)

volume increase opposes the normal tempering contraction in much the same way that the volume increase during martensite formation opposes purely thermal contraction in the quench — with significant effects on the pattern of residual stress.

Figure 2, by Howard Scott (*Transactions*, A.S.S.T., Vol. 9, 1926, p. 277), illustrates how tempering is responsible for shrinkage in steel in amounts increasing with temperature and at different rates, depending on the carbon and alloy contents. The greater the expansion during hardening, the greater will be the contraction during tempering. Figure 2 shows that a low-carbon steel contracts only 0.0005 in. per in. of length when tempered at 930° F., whereas two high-carbon toolsteels contract 0.0015 in. per in. at 930° F., and another 0.002 in. per in. at 750° F. Of interest also is the interval between 350 and 500° F. where expansion due to decomposition of retained austenite occurs in varying amounts in the high-carbon steels.

Figure 3, taken from a paper by G. V. Luerssen (*Transactions*, A.S.S.T., Vol. 17, 1930, p. 161) shows length changes on hardening and tempering, as affected by depth of hardening, which varied because of austenitizing temperature and hardenability. The effect of opposing volume changes due to thermal gradients and variable depth of hardening is reflected in the net length change during quenching.

From Fig. 2 and 3, it is apparent that the length changes during both quenching and tempering may vary greatly, even in similar steels. All changes in dimensions will contribute to a net state of stress that depends on the particular tempering temperature and the condition of stress prior to tempering. Some of the possibilities are as follows:

1. Any piece hardened uniformly throughout but with the interior in compression and the surface in tension will contract uniformly during tempering and the residual stresses will decrease uniformly.

2. A different situation occurs when different amounts of martensite exist throughout the cross section of the hardened object. For instance, consider a bar with an unhardened (pearlitic) interior: Tempering will cause no contraction of the interior but the hardened shell will contract as much as permitted by the unshrinking core. The stresses resulting will, of course, depend on the condition of stress in the steel before tempering.

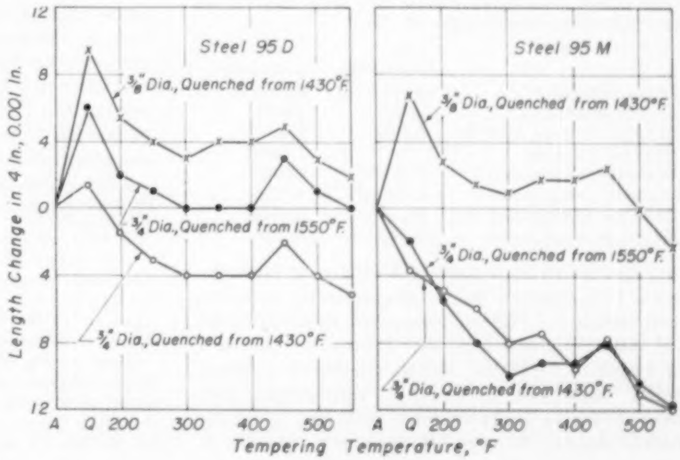


Fig. 3 — Length Changes in Two Carbon Toolsteels (Both 0.95% Carbon) During Quenching (Q) and After Tempering at Temperatures Shown. Specimens were cylinders 4 in. long. The annealed condition (A) is taken as zero. (G. V. Luerssen)

3. If the hardened piece has the surface in compression without any plastic flow having occurred, then tempering will progressively decrease the compression by shortening the hardened part until at some tempering temperature no residual stress will remain.

4. If the hardened piece has low residual stress due to plastic flow in the unhardened zone (or in the zone of hardening while it was at some elevated temperature) tempering will shorten the hardened region and create tensile stress at the surface.

5. If the hardened piece has the surface in tension, due to partial hardening at the center, then tempering will first increase the tension, because of greater contraction in the more fully hardened outer layer, and if the tension becomes greater than the yield strength, plastic flow will occur and will then decrease the tensile stress at the surface.

Thus, tempering may cause a change to either a more favorable or a less favorable condition of residual stress than that produced by hardening. Since depth of hardening influences the dimensional changes during tempering and therefore the residual stress, the result in any specific example is a compromise determined by the relative strengths of the hardened and unhardened zones in trying to follow the thermal and transformational changes. A small unhardened core has a slight retarding effect, preventing full length increase normal to the hardened zone. A large unhardened core can cause plastic shortening of the hardened shell, and a net decrease in length.

Dimensional Changes in 8640

To obtain some data on changes in fully hardened steel, two 6-in. bars of 8640, 1 in. diameter, were heated to the hardening temperature. One was oil quenched, the other was air cooled, and both were tempered at 1100° F. Measurements were made accurately before and after quenching and also after tempering:

	Normalized	Oil Quenched
Original length	6.0037 in.	6.0000 in.
Length as quenched	5.9995	5.9971
Length tempered 1100° F.	5.9994	5.9907
Original diameter	—	1.0008
Diameter as quenched	1.0005	1.0026
Diameter as tempered	1.0005	1.0015
Hardness as quenched	R_C 27	R_C 54
Hardness as tempered	R_C 23.5	R_C 35.5

The 8640 steel is capable of hardening throughout a 1-in. diameter bar. Oil quenching caused a contraction of 0.0029 in., compared with 0.0042 in. for the normalized bar; therefore, a net increase in length of 0.0013 in. can be attributed to hardening. This gain in length is considerably less than shown by Luerssen for a ⅜-in. bar of 0.95% carbon toolsteel hardened throughout. (See Fig. 3, on the preceding page.) Apparently the effect of thermal gradients is greater in the larger section. The outer layer, cooling and shrinking faster than the core, tended to drag the core along with it faster than dictated by the temperature of the core, thus shortening the core and consequently increasing its diameter. This, in turn, increased the diameter of the outer layer sufficiently to compensate for the volume increase due to hardening without causing any length increase. The shortening, then, was due to thermal gradients, not to transformation volume increase.

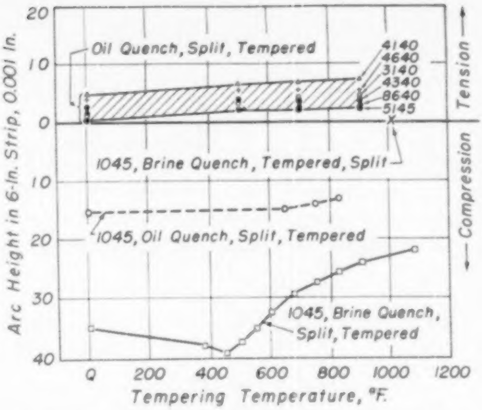


*Fig. 4 — Changes in Carbon and Alloy Steels During Tempering. All specimens 1 in. diameter, 6 in. long**

Tempering the hardened bar at 1100° F. caused it to decrease in length 0.006 in. The air cooled bar did not change when tempered. The 0.006-in. shrinkage of the hardened bar 6 in. long amounts to 0.001 in. per in. of length. When this shrinkage occurs uniformly throughout a hardened section, no residual stresses arise, but when a section having a hardened shell and an unhardened core is tempered, the case will stretch as it shrinks around the rigid core and, therefore, a stress of 30,000 psi. in tension will develop in the hardened zone for each 0.001 in. per in. of contraction. This will be added to the stress present in the hardened shell before tempering.

*For oil quenched 1045, the compressive stresses are estimated at 40,000 to 80,000 psi. At 0.040 in. on the compression scale the stress is estimated at 100,000 to 140,000 psi. In order to calculate these stress equivalents for 1045, an assumption had to be made concerning the shape of the hardness curve below the surface of the hardened bar. In the alloy steels the hardness gradient is much more gradual and the stress gradient would be more nearly a straight line. Therefore, the scale of stress versus arc height is different on the tension side, where 0.010 in. equals 28,000 psi.

With shallow hardening, the hardened part is in compression prior to tempering, so that tempering merely reduces residual stress in the hardened zone to values approaching zero. When a bar hardens almost throughout, the surface may be in tension; when through hardening occurs, the tension at the surface may be even higher.

Relative Magnitudes of Stresses

Length changes in hardened bars show the presence of residual stresses but do not indicate their magnitude or direction. To get some data on the latter, 1 and 1½-in. rounds made from 4340, 1045, 3140, 8640, 5145, 4140 and 1340 were split longitudinally after hardening, the pieces measured for arching, then tempered at various temperatures, and arc height measured after each tempering. Another set was hardened, tempered at 900° F. and then split. The measurements are shown in Fig. 4 and 5.

The stress level in hardened bars prior to splitting is higher than after splitting; that is, splitting relieves some of the residual stress, whether it be tensile or compressive. Therefore, after tempering, the split pieces show much less stress relief than the pieces tempered before splitting. Figure 4 deals with the effect of tempering on stresses created in hardening 1-in. diameter bars of 1045 and six alloy steels cut longitudinally after hardening and before tempering. All the alloy steels showed tension at the surface after hardening, and tempering increased that tension slightly because the surface layers were shortened more than the layers toward the center.

However, 1045 as hardened had compressive stress at the surface and the magnitude of this stress was much greater in the brine quenched than in the oil quenched samples. During subsequent tempering, shortening of the hardened zone progressively released the compressive stress at temperatures above 400° F., whereas below 400° F. decomposition of retained austenite resulted in expansion instead of contraction. The result from one bar of 1045 that was tempered before splitting is indicated by the point marked *X*, showing complete relief of stress and indicating the greater effectiveness of the high residual stresses in causing creep and consequent stress relief during tempering.

Additional tests to determine the effect of section size and hardenability on relief of stresses in tempering, when tempering was done prior to splitting the bar, are summarized in Fig. 5. The vertical bands denoting stress are arranged according to the hardenability of the steel, with the steel of lowest hardenability plotted at the left. Two measurements, one for each half of the split bar, determine the stepped appearance of bands.

The residual stress trends from compression (when hardenability is low) to tension, increasing with hardenability. This trend is especially apparent in the 1½-in. bars. In general, tempering for 1 hr. at 900° F. causes a decrease in residual stress but usually some stress remains. Note that the 1-in. bar of 4130 steel showed compressive stress at the surface after hardening, but after tempering a reversal to tensile stress had occurred. This is clearly the result of a much greater contraction, caused by tempering, in the surface layers than in the core.

Although the difference in residual stress is great among steels 8640, 5145, 4640 and 3140, due primarily to differences in hardenability, it is important to remember that the variation in these four steels is well within the range of hardenability that would be encountered in a number of heats of any one of these steels. This point is illustrated in Fig. 6, on the next page, which shows the hardenability curves for four of the steels in relation to the H band for 3140 steel. It is evident that as hardenability varies from heat to heat of any one

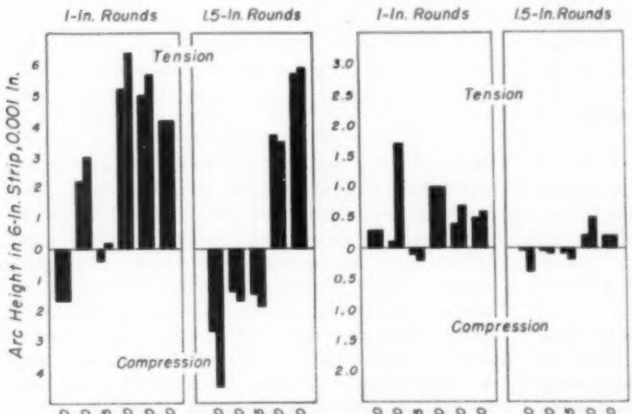


Fig. 5 — Effect of Bar Diameter and Tempering on Stress Condition. For the 1-in. rounds, 0.001 in. of arc height is equivalent to 2800 psi.; for the 1½-in. rounds, 0.001 in. is equivalent to 4200 psi.

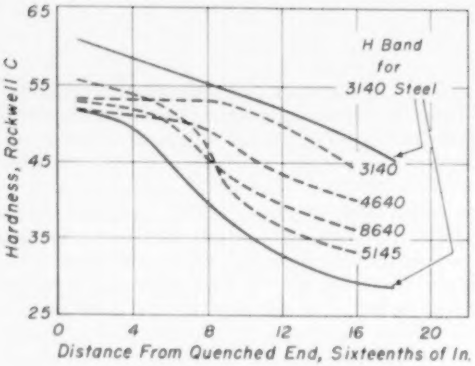


Fig. 6 — Hardenability of Steels Tested

steel, we can expect a decided change in the amount and direction of residual stresses in parts made from that steel. This variation of residual stress as hardenability varies within the H band for any alloy steel is probably the largest and most serious result of hardenability variation.

Stress Relief and Creep

The factors affecting the magnitude of residual stress during tempering are the creep characteristics of the steel, the amount of residual stress and the temperature. Figure 7 gives the tensile strength, yield strength, and stress for 1% and 0.01% creep in 1 hr. for a carbon steel at various subcritical temperatures. At the temperatures in question, the modulus of elasticity of steel is about 15,000,000 psi. Therefore, 0.010 in. per in. elastic extension would require 150,000 psi. stress and 0.0001 in. per in. would require 1500 psi. From the curve we see that at 750° F. a stress of 45,000 psi. will cause 0.010 in. per in. creep in 1 hr.; that is, 45,000 psi. will cause a strain which, if elastic, would correspond to a stress of 150,000 psi. As soon as flow occurs, however, the residual stress is reduced in proportion to the amount of creep. When enough creep has occurred to reduce the residual stress to 30,000 psi., that amount of stress will cause only 0.0001 in. per in. creep per hour; that is, it will relieve only 1500 psi. stress, so that at the end of an hour there should be 28,500 psi. stress. If the residual stress is 30,000 psi. in the hardened piece, tempering for 1 hr. at 750° F. would also cause 0.0001 in. per in. creep or 1500 psi. reduction in residual stress. Following this line of reasoning would bring us to the conclusion that the residual stress remains at a fairly high level when the steel is being tempered at 750° F. However, the experimental evidence shows that this is not always so, probably because of the differences in length changes that occur in adjacent regions of different hardness, acting to

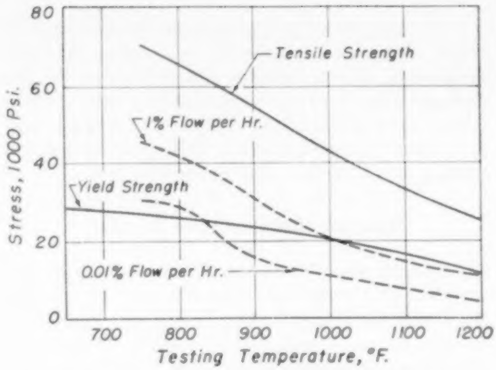


Fig. 7 — Strength of Annealed Cast Carbon Steel at Elevated Temperatures. (J. J. Kanter)

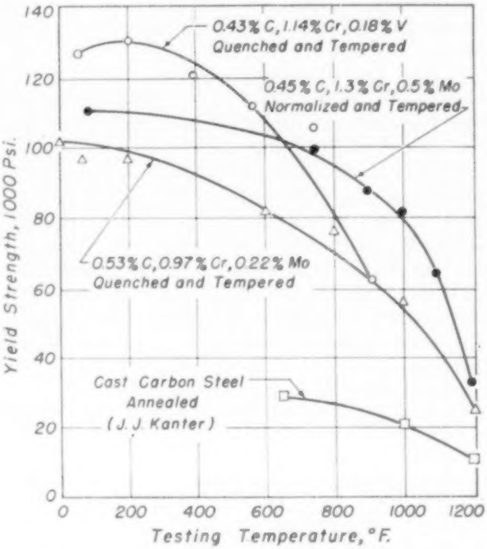


Fig. 8 — Yield Strength at Elevated Temperature

augment or oppose the relief of hardening stresses.

Figure 8 gives an idea of the creep in alloy steels, as compared with plain carbon. The yield strengths at elevated temperatures for the three alloy steels are much higher than for plain carbon steels. Therefore, residual stresses in the more creep resistant alloy steels are likely to be correspondingly higher after tempering than in carbon steels with the same stresses as quenched.

Conclusion — Unfavorable residual stress may be present after tempering and should be determined experimentally to be sure that the steel is being used to best advantage.

Critical Points

By The Editor

WITHIN recent months THE EDITOR was privileged to inspect manufacturing operations on Uncle Sam's most powerful bombers. One whole day he tramped through Convair's mile-long plant in Ft. Worth, Texas, with FRED STANLEY, research engineer, and gradually acquired an idea of the great size of the B-36, there being made. In Wichita, Kansas, he was shown about by KEVIN FITZGERALD of Boeing's Public Relations on a motor tour of the equally large plant just getting the B-47 under production. This is no place to discuss the relative merits of the two ships, even if the essential facts were known and available for publication. One can record the visual impression that the two bombers are designed for totally different missions; Convair's long-range B-36 looks something like an outsized "Liberator" bomber (B-24) of the last war, whereas Boeing's fast B-47 seems more sleek, with the swept-back, narrow, thin-edged wings characterizing a jet plane. It is, indeed, jet propelled with six engines, whereas the B-36 has six pusher-type Pratt & Whitney 3500-hp. engines plus two pairs of jet engines, one at each wing tip, to increase speed during emergencies. The B-36 is heavily armed, like its World War predecessors, with remote-controlled guns in retractable blisters; the B-47, like a naval destroyer, seems to rely more upon speed for its defense and has only three men aboard. Both ships have armored, pressurized cabins; the B-36 has also a pressurized crew compartment near the tail, connected with the nose end by a tubular manway, 85 ft. long, through which you ride prone on a little flatcar.

Big bombers

AT BOTH these plants, THE EDITOR was impressed by the amount of time necessary to get started on machines of this sort. It only re-emphasizes the truism that, in war, *time* is of the essence. For example the Wichita plant had been entirely cleared of its wartime machinery for making "Superforts", yet it took about a year to install the machine tools, build the jigs, and recruit the staff to build the B-47. Noteworthy to this observer was the *size* of some of the tools. Quite evidently the subassemblies are made of larger units than ever in bending rolls (with superfinished surfaces to avoid marring the stock), Hufford stretch-formers occupying the space of a city lot, machines built like planers with 8-ft. clearance for taper-milling the wing skin (5/8 in. thick at the fuselage to 3/16 in. at the tip).

Heavy construction

Convair's B-36 was put on the drawing boards in 1941, when it seemed there would be no landing fields nearer Germany than Newfoundland. The prototype was flown five years later! Production model No. 1 was delivered in mid-1947. Six years seems a long time, but it is a fact that not a single American airplane, big or little, saw service in World War II that was not on the drawing boards *before* the war started.

At such a completely integrated plant as at Ft. Worth, a bewildering variety of metal-working operations and metal treatment and finishing equipment is necessary. Operations are by no means confined to aluminum. About half of the skin is of magnesium sheet, and engineers have turned to stainless steels for places near the jet engines, where temperatures are uncomfortably high. Stresses in the B-36's 163-ft. fuselage — a cylinder 12½ ft. in diameter — are carried across the bomb-bay area by two heavy trusses, like a highway bridge. (The B-47 is principally of 75-S alloy and is of semimonocoque construction; the main cross member, where the wings join the fuselage, is made of two of the heaviest aluminum forgings ever, bolted together at the center.) Lots of welding is done at Ft. Worth — welding of magnesium fittings, monel metal heat exchangers, stainless steel exhaust systems, Cr-Mo steel engine mounts. The latter, after quench hardening, are tempered in massive cast iron jigs to bring them out unwarped. Not the least of the problems in materials and design centers in the house-high gear for landing such a 100-ton craft at 100 miles an hour. To say that at take-off it carries 60 tons of high-test gasoline in self-sealing tanks may not mean as much to the average man as the thought that this is enough to drive a Chevrolet 15 times around the world.

ONE TRICKY joining method was observed: Outer skin sections of B-36 are fastened to dimpled stiffeners by thin sheets of thermoplastic resins, good for 2500-psi. shear strength. During the mild heating required for setting the adhesive, the assembly is covered by a rubber blanket, battened down around the edges; a partial vacuum establishes the necessary hold-down pressure — very ingenious! Would that our ingenuity had solved the problem of spot welding these big aircraft together. To THE EDITOR's way of thinking, the metallurgists and welding engineers failed in this conspicuous bottleneck. Fitters, drillers, countersinkers, riveters, rivet-head tappers and polishers still swarm over the assembly jigs, consuming astronomical numbers of man-hours of tedious labor, man-hours that could poorly be spared in some future emergency. This is said with full appreciation of the difficulty of welding the heat treated strong alloys, of the great amount of study that has been given the problem, and of some progress toward eventual success. Nevertheless it is apparent that stationary and portable spot welders are not yet reliable enough for aeronautical engineers and constructors to use on joints of major importance.

Can you weld it?

WICHITA is diversified in the business of building aircraft, which includes the small Cessna, the medium-small Beechcraft and the huge B-47. It would seem that their problems are similar in kind, different in magnitude. *Costs* must evidently be scrutinized more closely in commercial and private aircraft, yet the care in building the small ones is so meticulous that the private pilot — once he sees and appreciates it — can be certain that his ship will not fail him. Labor-saving designs are more in evidence. For example, PHIL KOERNER, assistant metallurgist for Beechcraft, showed some magnesium control surfaces, formed hot, of sheet thick and stiff enough so no internal bracing is needed. Many brazed assemblies are in evidence: Examples are an oil cooler of aluminum, furnace brazed as a unit, and cast iron parts, silver brazed together after the graphite on the mating surfaces has been removed electrochemically. KOERNER is also proud of the landing gear — cheaper, lighter and stronger than before. Its main unit is a bronze-to-steel combination, brazed with alloy of high melting point; this is then machined and another attachment brazed on with alloy of lower melting point. . . . . GEORGE BAUGHMAN, chief process engineer for Cessna, told an interesting story of postwar conversion. Possessing a complete department for machining landing gear for fighters, it was thought that some business could be done in hydraulic cylinders and valves for harvesting machinery. They found that, while the cylinders could be made with heavier parts, the machine work was just as fussy and practically to the same tolerances. Hurdle No. 2: Whereas the landing gear cost $200 each, the farmer wanted his value for five! Needless to say, the resulting compromise favored the farmer heavily.

Small craft

SINCE St. Louis is a prime center of the chemical industry, it was fitting that a visit be made to Nooter Corp., which manufactures process equipment. Started in the mid-90's as a boiler shop (power plant work "on the site" is still a most important activity), the progressive founder early recognized the importance of brass, bronze, nickel and aluminum for vessels used in refineries, chemical plants, dairies and breweries, and adapted them to his fabrications. Then came the more recent stainless steels and higher alloyed "Hastelloys". The sprawling plant, alongside the Mississippi, shows signs of this continuous growth. Welding — especially submerged arc, helium shielded arc, and atomic hydrogen — is the universal joining method, and the observer indeed concludes that without it one could hardly build many of the modern units, whose smooth exteriors often hide a maze of tubes, baffles, diaphragms and channels. Nooter's "metallizing" department is also most highly developed. Originally intended for lining steel equipment, abandoned since the advent of clad plate, it was resurrected with improved automatic equipment capable of building up solid deposits of any desired thickness. So far most of the work has been corrective, in the sense that metal has been sprayed on corroded underframes of railroad passenger cars operating on seacoast lines, for example, or worn metal replaced on journals or spiral conveyers. However, the history of other metallurgical methods has so often included a preliminary phase when it was used on a small scale in repair shops before it proved itself competent for important manufacturing operations that it is possible the spraying of molten metal droplets through a protective flame will become the preferred way to produce clad or composites in many situations. . . . . In a discussion of the economics of clad plate and lined equipment, metallurgist PAUL DOWLING said that every job was an individual problem, depending on the freight charges on raw material from mill to fabricator and on the completed equipment from fabricator to site,

Welded chemical equipment

on the relationship between thickness of cladding and steel backing, on the specific cost of the alloy cladding, on the amount of hand and automatic welding needed, and on the necessity of stress relieving or desensitizing heat treatments. For example, it turned out to be cheaper, in one important group of catalytic cracking units for a near-by refinery, to line the completed carbon-steel shell with Type 405 stainless steel strip, 12-gage thick, than to build it of clad plate. The 4-in. strip could be easily bent and trimmed to conform to the cylindrical, domed, or coned surfaces, and welded along the butts with current adjusted so as to give about 1/8 in. penetration into the steel foundation. (Less penetration meant incomplete bonding and tended to leave tiny cracks along the bead at the faying surfaces; more penetration favored excessive dilution with carbon steel backing.) Type 405 contains enough aluminum so the heat affected zone is not hard; thus the completed units needed only a stress relieving anneal at a moderate temperature. . . . . DOWLING at present is trying to devise quenching apparatus for the heavy equipment of stainless steels that must be cooled rapidly from stabilizing temperatures. Many experiences have proven that more damage than improvement is often given a complex structure during a heat treatment specified in detail by the purchaser — often erroneously or even quite unnecessarily. If heat treatment is imperative for the alloy best fitted for a given service, the *inside* of a container is the part that must resist the corrosive chemicals; obviously, the *inside* should be put into most resistant condition by the quickest possible quench; yet the cooling water hits the *outside* of the vessel, and the inside cools at a moderate rate. Did you ever think about the difficulty of getting a heavy stream of water *inside* such a red-hot vessel, as big as a boxcar, and quenching each spot of the inner surface uniformly and quickly?

Heat treating large vessels

IN SOUTHERN California, THE EDITOR was vastly pleased with the evident signs of postwar industrial activity, notable examples being concentrated at Vernon on the outskirts of Los Angeles. Among them is Norris Stamping & Mfg. Co., characterized in last August's *Fortune* as a "strikingly handsome and well-kept plant, making a shamelessly old-fashioned success". Highly efficient production lines, worked at speeds that would please HENRY FORD, by men whose incentive is a generous profit-sharing plan, turn out automobile wheels, enameled bath tubs and sinks, compressed gas cylinders, steel cartridge cases, ammunition containers made of aluminum, and a line of stainless steel cooking utensils. . . . . Especially interesting are these shining pots and pans. They are made of Type 302 stainless steel in one draw. The vapor seal is formed and the bead is rolled without anneal from a flange which is about C-40 hard. They are exceedingly strong and enduring and do not "season crack" in an accelerated test if the nickel is not allowed to fall below 8.5%. A smooth electrodeposit of copper plated on the bottom equalizes the temperature — turns it into "jewelry", as the workmen call it.

Los Angeles —industrial metropolis

NORRIS was conspicuously successful in its wartime manufacture of steel cartridge cases for Army and Navy (3 in. and larger), the staff having solved the multitude of problems in an original way, unhampered by tradition (described by FRED ARNOLD, director of research and development, in various contemporary issues of *Metal Progress*). At present this plant is the only producer in the United States; a complete production line is operated under a Navy contract to devise even better methods leading to a stronger product — for the improved propellent powders now in use are too much for the conventional brass cases; the thicker steel cases may even require some alloy for uniform hardening response at the breech. At present the material is a plain carbon steel. Chemical limits are rather close except for carbon, which is specified 0.24 to 0.34 (although actually delivered with mill analysis selected to 0.28 to 0.30%). Such close limits avoid any necessity for adjustment of the numerous softening anneals at various stages of the cold reduction. Such annealing is done with normal atmosphere; the light scale is pickled off — a necessary operation to roughen the surface for "tooth" for lubricant. Lubricant, by the way, is plain laundry soap applied as a hot water solution, 1 lb. per gallon. Low-alloy steel, carburized and oil hardened, is suitable for punches after chromium plating; cemented tungsten carbide is used for dies. The finished case is zinc plated for corrosion resistance. Navy ammunition, in addition, is further protected by airtight aluminum canisters.

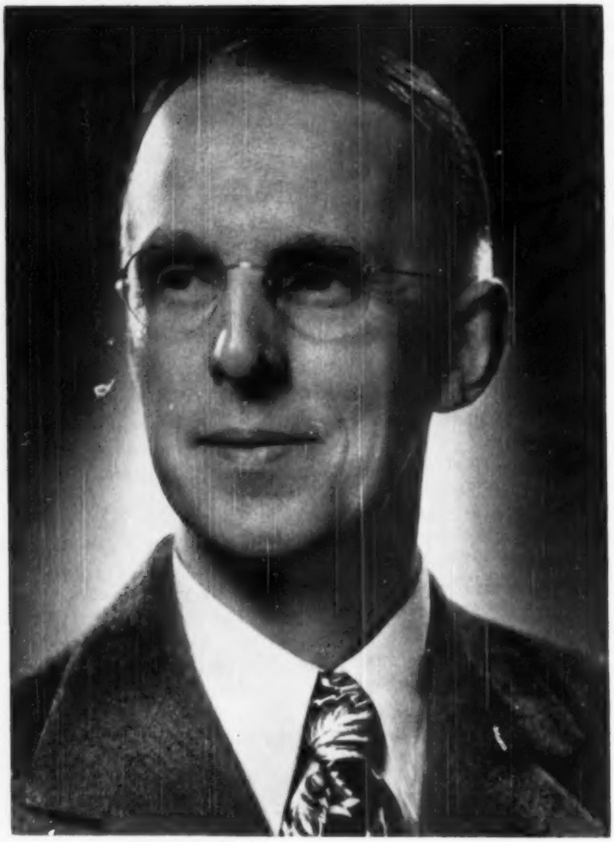
Extra deep drawing of steel

Mohammed and the Mountain

Sign observed recently in Colorado:

CANON CITY
The Home of the Royal Gorge

President, American Society for Metals



Arthur Eldridge Focke

A Biographical Appreciation

FIFTY MILLION American boys can't be wrong when they contend that the bicycle is here to stay. A good part of this contention is based on reliability of the familiar chain drive and serves as an indirect testimonial to ARTHUR E. FOCKE, chief metallurgist of the Diamond Chain Co., who has been long and intimately concerned with the metallurgy of roller chain and with its serviceability in devices ranging all the way from kiddie cars to jumbo-size oil-well drilling systems.

A direct and more specific testimonial comes from GUY WAINWRIGHT, president of Diamond Chain: "ARTHUR FOCKE has the true scientist's unlimited curiosity, combined with the engineer's practical approach to day-by-day problems of an industry that has to get out a product to live."

This introduction establishes our subject in his present environment and reveals his technical versatility. What steps led to the development of this scientist-engineer?

ARTHUR ELDRIDGE FOCKE was born in Cleveland, June 17, 1904. His father, FRANCIS ARTHUR FOCKE, was one of the pioneer engineers in the telephone industry. Before the youngster finished high school, his family moved to Columbus, where he attended Ohio State. In his undergraduate work, he became interested in X-ray diffraction and stayed at the university for advanced work in that field. His chosen research project was tungsten wire. This led to an arrangement whereby he did the experimental work for his thesis at the Cleveland Wire Works of the General Electric Co. ZAY JEFFRIES was presiding over the Wire Works laboratory at that time and FOCKE continued JEFFRIES' study of metallurgical factors affecting the quality of tungsten filaments for lamps. After Ohio State granted him the Ph.D. degree in 1928, the young engineer continued with General Electric for a year, working on copper-tungsten welding electrodes. Also, Carboloy was just reaching the stage where it could be introduced to the metal fabricating industry, and it was FOCKE's job to supervise the technical phases of transferring this development from research to production. As an outcome of his G. E. experience, he joined P. R. Mallory Co. as chief engineer in 1929, and in October 1930 became research metallurgist for Diamond Chain in Indianapolis.

ARTHUR FOCKE's experience for the last 19 years has been typical of many ⊕ members in plants big enough to have multiple metallurgical problems, but small enough so that a metallurgist is not a specialist in just one or two problems.

As chief metallurgist in a mechanical plant, he spends much time with matters that are often considered a part of mechanical engineering. He is continually moving back and forth over the imaginary boundary between mechanical and metallurgical engineering.

The range of this engineering scale may be compared to the musical scale, with mechanical notes played left-handed in the bass and the more difficult metallurgical solos scored in the higher reaches of the treble clef. On the octaves of this scale, ARTHUR FOCKE has acquired the technique of a virtuoso without developing any characteristics of the prima donna. Whether it be simple chords or complex obbligatos, he keeps the melody in tune, changing from treble to bass as the score requires and sometimes sharing the music in a duet or trio. He likes to improvise here and there and throw in grace notes, but there is no breaking out into anything so unrestrained as a "jam session". And he has never been known to take a three-bar rest!

One day Dr. FOCKE is consulting with the design department on wear problems or residual stresses; the next day he may be a furnace engineer; then there will be a statistical correlation of laboratory fatigue testing with the service behavior of his favorite product; follows an investigation of how tight is a press fit; then a conference with the purchasing agent on some restrictive specification.

Thus, FOCKE the metallurgical engineer becomes FOCKE the plant consultant and — he would probably add — FOCKE the learner.

So it has been for 19 years, a steady process of learning about various and sundry engineering problems. But that is only half the story. A clue to the other half is found in the last line of Dr. FOCKE's biography in "American Men of Science". Here are listed his special interests and here we find the entry "metallurgical education", revealing a long and continuing interest in teaching.

When he finished his academic training, ARTHUR FOCKE set himself this schedule: five years in industry and then return to university teaching. $1928 + 5 = 1933$. In 1933 there was a depression and it was unfashionable to leave one's job voluntarily. But a depression did not change Dr. FOCKE's attitude toward education.

He has satisfied the teaching urge by basic educational work in his plant and in the local ⊕ chapter. In informal discussion groups and semiformal courses — but never in any formal or pedantic way — he has unselfishly transferred his engineering knowledge and philosophy to associates. T. L.

The Multiple Uses of Platinum Metals

By F. E. Carter
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The total amount of platinum metals available in this country is only about 13 tons per year, but the uses are exceedingly diverse. Consumption in 1946 was distributed as follows: jewelry 46%, electrical 27%, dental and medical 13%, chemical 10%, other 4%. Some particulars of the various applications, especially in industrial processes and equipment, are discussed in this article.

THE "noble metals" comprise silver, gold and the platinum metals; these are also known as the "precious metals", particularly in the jewelry industry. The chemical and metallurgical industries know them as noble metals because of their resistance to acids and to atmosphere at elevated temperatures.

Gold and silver are among the oldest of known metals, having been recovered and used by the ancients; on the other hand, the platinum metals are quite modern, dating only from the eighteenth and nineteenth centuries.

The excellent anti-corrosion properties of platinum led to its first industrial use, namely for crucibles and dishes in the laboratory, where it supplied a "long-felt want", as the preface writers of a modern textbook put it. The curiosity of the early nineteenth century chemists led to the discovery that their platinum was not a pure metallic element, but actually contained small amounts of other closely allied metals; one after another, iridium, rhodium, palladium, osmium, and ruthenium were isolated and their properties investigated. Commercial platinum is platinum from which the last traces of these by-metals have not been removed. The by-metals can hardly be classed as impurities since they have approximately the same properties as elementary platinum; indeed, for some uses, their presence may constitute an improvement. However, in many applications it is necessary to use the purest platinum possible and the chemist has evolved methods of completely separating the five by-metals from the parent. Platinum of purity better than 99.99% is in daily industrial use for thermocouples and resistance thermometers.

The by-metals are frequently rejoined to the platinum to form useful alloys which are, in general, of greater industrial value than is the pure metal itself. The alloys are harder, have greater strength and usually are more corrosion resistant; they have higher electrical resistivities and lower temperature coefficients of resistance and in some instances have improved efficiencies as catalysts for certain chemical processes.

The layman probably believes that platinum finds its only use in highest class jewelry manufacture; the technical man may feel somewhat superior because he knows that, in addition, it is useful for laboratory ware. Both are wide of the mark, as a short account of the uses of platinum in many different fields will show.

Foodstuffs — The growth of vegetation requires nitrogen in the combined state; nature converts the elementary nitrogen of the atmosphere into assimilable forms by means of bacteria, but nature is slow and the world's population is growing so fast that the chemist had to help the situation by speeding up the conversion of nitrogen. This he does by synthesizing ammonia by combining nitrogen of the air and hydrogen; then he oxidizes this ammonia to nitric acid which subsequently produces the soluble nitrates essential for the growth of plants. It is in the process for oxidation of ammonia that platinum comes into the picture. Superficially this oxidation is a simple process; one volume of ammonia is mixed with nine volumes of air and passed through a few layers of a fine-mesh gauze of platinum or platinum-rhodium (Fig. 1); the catalytic gauze promotes the reaction between the ammonia and the oxygen in the air, whereby nitrogen oxides are formed; these in turn are easily converted to nitric acid and nitrates. The reaction is exothermic, so the necessary gauze temperature of 1470 to 1650° F. is reached without

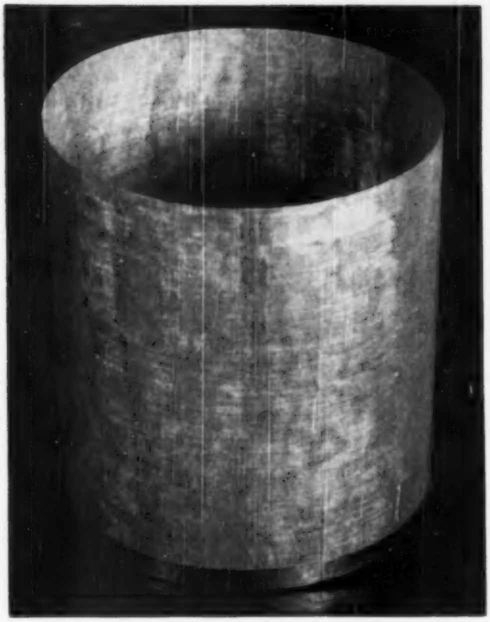

Fig. 1 — Platinum Gauze Catalyst Used in Ammonia Oxidation During the Production of Nitric Acid. Cylinders are generally used in smaller installations, particularly to produce the nitrous gases for the chamber process of manufacturing sulphuric acid. Large installations use flat pads of gauze

application of any external heat and it takes place with an efficiency approaching 100%.

Yes indeed, the population of the world would be hungrier if platinum were not present to help.

Clothing — Early man depended on animal skins for clothing himself; later he learned to leave the skin but took for himself the animal's clothing in the shape of wool. Then he found he could weave some vegetable products like flax and cotton into useful garments. Finally the chemist cast his eyes on the trees and decided he would make wearing apparel from them. He reduced the trees to wood pulp, treated this with chemicals to dissolve it and pushed it through the tiny holes of a spinneret and into a precipitating medium, whereby continuous fine filaments are formed. Hence we have rayon, nylon and many other synthetic fibers. The most important factor in the process is the spinneret, which must have holes absolutely round and uniform in size from one hole to the next; it must be made of noncorroding material and the holes must be readily cleanable by acid or heat. Platinum and its alloys excellently fill the bill as a spinneret material and today hundreds of thousands of these little cups are busily producing the beautiful modern materials of clothing and other decorative fabrics (Fig. 2).

Dentistry — The proportion of the annual production of the platinum metals that goes into people's mouths is much larger than is generally known; the present high state of perfection of orthodontia work would not be possible without the gold alloys that are strengthened by additions of platinum and palladium. Further, many of these alloys are white, which is considered esthetically preferable to yellow gold. Platinum finds much use in the form of dead-soft foil for lining dental cavities, and palladium plays its part in the millions of tooth pins in use today.

Medicine — Platinum metals are present in many of the instruments used by the medical profession. In the X-ray tube platinum is required as lead-in material and may be used for the target; the "hardness" of the tube may be varied by means of a palladium appendage which on heating can diffuse hydrogen into or out of the X-ray tube as desired. Platinum alloys with up to 30% iridium make the best hypodermic needles; they can be sterilized for re-use by heating, never tarnish and are always ready for action. Cautery tips are made wholly or partly of the platinum metals.

Lighting — The importance of platinum in the lighting field is not what it was fifty years ago. Then, in the earlier days of the electric light bulbs, each bulb required two short lengths of platinum to seal the leads through the glass, as it was the only material that had the same coefficient of

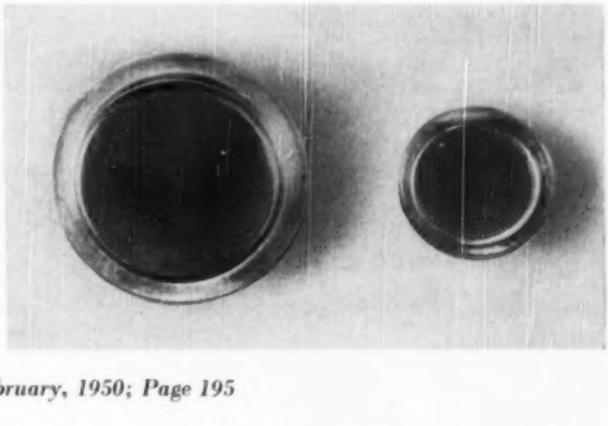

Fig. 2 — Platinum Spinnerets Used in the Manufacture of Synthetic Fibers

expansion as glass; also, the earliest filaments were of platinum metals. Now, other alloys and other glasses have been developed that are suitable for the purpose, so that platinum, fortunately, is not required. The light standard is specified as the amount of light emitted from platinum at its melting point. This and a few other indirect applications constitute the only residual uses of platinum metals in the lighting field today.

Heating — Platinum igniters and contacts are essential parts of various oil burners, gas lighters and the like; actual heaters using platinum depend on the catalytic activity of the metal. In these there is a slow combustion of the fuel on the surface of the platinum so that a low, steady amount of heat is continuously developed.

Art — Jewelry, which accounts for a large percentage of all platinum sold, need only be mentioned, since the use of platinum and of palladium in the best class of jewelry is well known. Articles of cheaper materials are widely electroplated with rhodium; silver pieces are rendered nontarnishing by this process. Chinaware is decorated with platinum, and palladium leaf is used for the lettering of book covers and, in place of gold, for the edges of the leaves. In photography, platinum and palladium prints have been used, although modern silver prints leave little to be desired.

Literature — This heading is introduced simply to mention the use of platinum metals, osmium and iridium, for tipping of pens. All that is written by such pens is not literature, and most literature is penned by a typewriter; nevertheless, the platinum metals are being used for writing and are available to anyone who wants to use them.

Science — All applications of the platinum metals in the construction of delicate instruments might be included here. One can mention galvanometer suspensions, electrical measuring devices of all sorts, special radio tubes, thermocouples and resistance thermometers. Above all these comes the great field of electrical contacts, in which the platinum metals are preferred where absolute surety of making contact is required; other materials eventually become coated with an oxide or sulphide, so that, especially with small currents and light contact pressure, the circuit is not "made". Some types of controlling equipment require exceedingly hard contacts and several platinum metal alloys are available for this purpose.

Technology — Under this broad heading the applications of the platinum metals are so numerous that only a selection can be made. First of all, mention must be made of the glass industry where platinum and palladium are being used in ever-increasing amounts. Molten glass has a very severe corrosive action on refractories, which are now being protected by a liner of platinum metals; with such protection the life of the furnace, feeder-ring and orifice is extended many fold. The electrochemical industry uses considerable quantities of platinum as anode material; it is insoluble under most conditions so that the electrode life and the purity of the product are much improved by its use.

The catalytic field is a story in itself. Platinum and palladium catalysts are used for hydrogenation and dehydrogenation in many important organic chemistry processes; in the inorganic field there are the contact sulphuric acid process and many more. The chemical industry is adopting more and more the use of rupture disks (Fig. 3) as the simplest form of safety valve; for handling corrosive gases or liquids, platinum is necessary.

The above headings indicate the wide diversity of applications of the platinum metals and their essentiality in many fields. It is rather startling to realize that the sum total available in a year from all sources is only about 13 tons, or a cube of metal about 4 ft. on each side. This 13-ton block of metal came in 1948 from the following sources:

Imported pure metals	8.7 tons
Recovered by refiners	
Reworked material	2.5
Imported crude material	1.3
Domestic production	0.5

It will be seen that we are dependent on imports for about two thirds of the platinum metals we consume; domestic production, chiefly from Alaska, is comparatively small and the balance is made up by reworking material that has already done its job. Fortunately, the platinum metals are rather permanent materials and, after refining, can again be made available; this is most desirable, since it is obvious that the world supply must be conserved as much as possible. It would be difficult indeed to find a substitute for metals that have such unique properties.

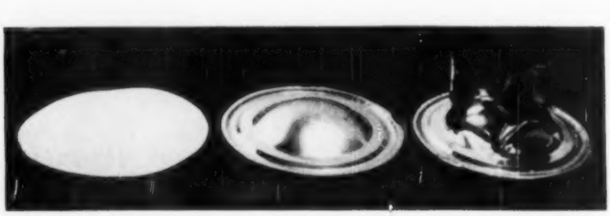

Fig. 3 — Platinum Rupture Disks. Original flat disk (left); bulged, as installed (center); and ruptured

Scovill's New Mill for Rolling Brass Strip

By Harold J. Roast
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Consulting Engineer
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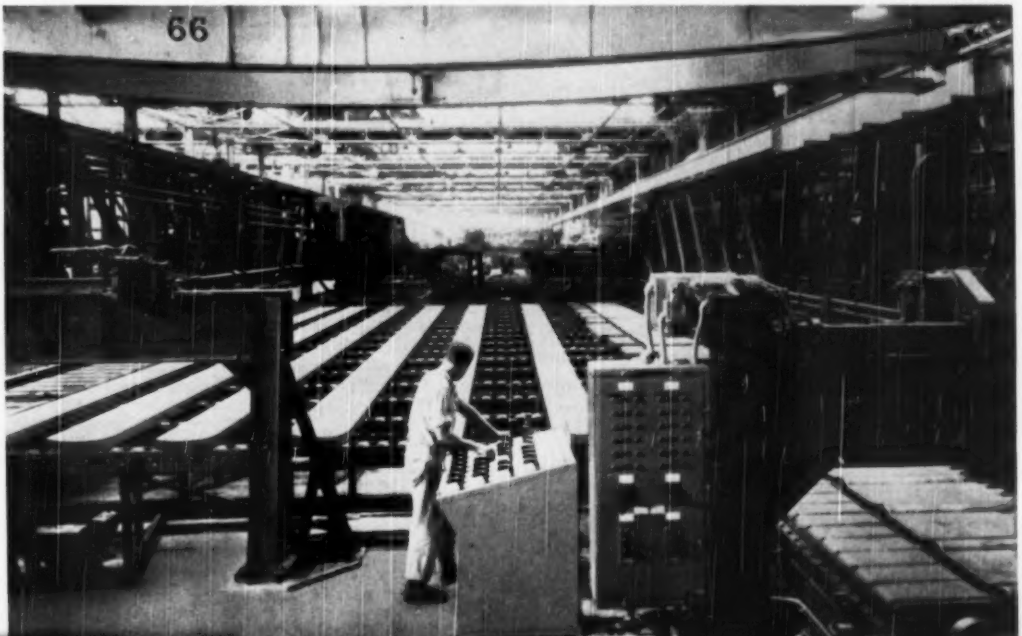
TO MEET a demand for brass strip precise in dimensions and constant in metallurgical properties, and in heavier and heavier coils, Scovill Mfg. Co. has built in Waterbury a $10,000,000 mill, operating in straight line. In the words of C. P. Goss, vice-president, "The new strip mill is the realization of an engineer's dream — a production line which organizes, in one straight flow, all the equipment for producing cold rolled brass, from flat metal casting to packaging of the finished strip and sheet."

Heart of the new mill is the unique continuous casting machine for slabs, described in last month's *Metal Progress*. To one familiar with conventional brass casting methods, where metal, melted in batches in relatively small furnaces, is poured into tall, narrow slab molds, it is apparent that the new scheme at the very outset will avoid chemical variations melt to melt, and vertical segregation within the ingot, and thus produce brass strip of unexampled chemical and microstructural uniformity, end to end and coil to coil. To a fabricator of brass articles these advantages mean smooth, low-cost output at the highest rates of production.

Like every other employer of labor in the United States, Scovill Mfg. Co. has long faced a steadily mounting wage bill. Its labor-relations history has been an enviable one, there having been only two short strikes in the last 30 years. Good working conditions have been a prime reason, but in the past an improvement in working

Fig. 1 — Delivery and Storage Tables for Breakdown Mill. Note general mechanization in most up-to-date form



conditions has often meant an increased payroll! Over and beyond the gain in quality of the output, the new mill has therefore been designed to reduce to the minimum the man-hours of labor; this, in truth, is absolutely necessary for the sizes and weights of the slabs and coils in process. The visitor to the mill is struck with the relatively few workmen in sight; officials estimate that 70% of the savings in production costs is due to mechanization (the saving of manual labor) in the mill, and 30% in the continuous casting department. As is always true when machinery replaces human labor, the immediate effect is to reduce employment somewhat — "technological unemployment" is the term for it. However, the resulting improvement in product and its introduction into new fields will more than make up for temporary displacement of man power. This has been the unvarying result of the "labor saving" devices which American industry has utilized since our history began.

A certain degree of flexibility — or, rather, adaptability — which the older brass mills possess is sacrificed in the new, mechanized, straight-line operation. On the other hand, careful provision is made for anticipated changes in market demand (weight of coils, dimensions of strip, and temper). Obviously, a certain large quantity of a single alloy must be produced before furnaces are drained and mill controls adjusted. The economical minimum for strip is placed at about 100,000 lb. Furthermore, it will be observed from the flow sheet and the subsequent text that all reduction is by cold rolling. This permits the mill to handle leaded brasses, which may represent 20% of total production (hot rolling requires lead below 0.02%), even though principal production will be in nonleaded alloys of copper and zinc, notably gilding metal (95% Cu), commercial bronze (90% Cu), red brass (85% Cu), cartridge brass (70% Cu) and yellow brass (65% Cu). By the very nature of continuous operations, it will not be economical to produce small tonnages of specialties in the new mill.

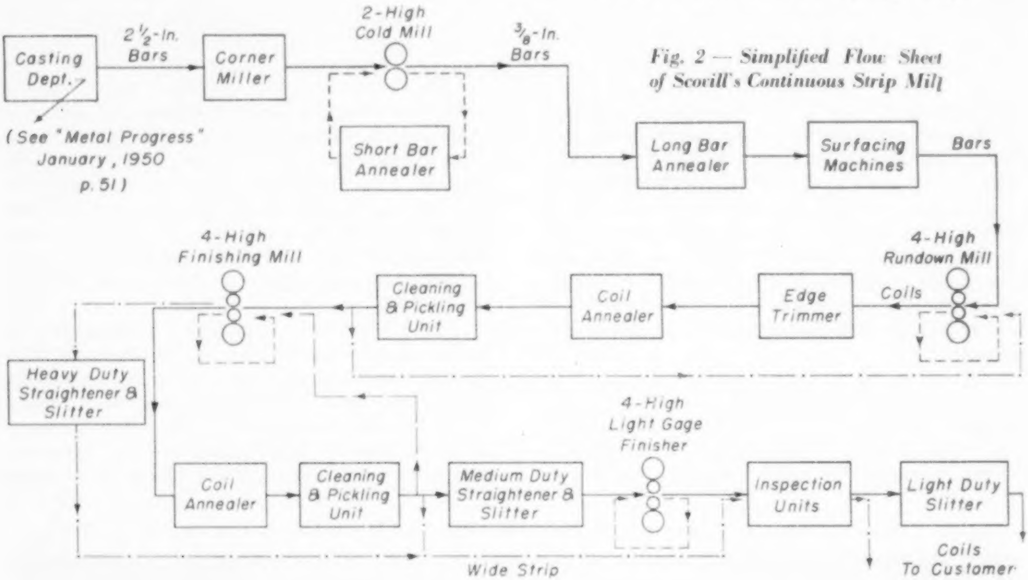


Fig. 2 — Simplified Flow Sheet of Scovill's Continuous Strip Mill

Breakdown

A flow sheet of the mill (Fig. 2), as designed by Stone & Webster Engineering Corp., indicates the major pieces of equipment and their interrelation. Preliminary studies continued intermittently for four years along the following lines:

Analysis of production pattern for postwar business.

Tentative layouts of rolling mill to meet the anticipated production requirements.

Estimate of construction cost of new mill.

Production cost study: Comparison of estimated cost of production in proposed new mill with cost of production in existing mill.

Many alternative programs were studied, each requiring preliminary plans and estimates. For

each alternative, exhaustive studies determined the most effective bar size, the most efficient capacity, speed and other characteristics of the rolling mills and their auxiliary equipment.

The cast bar, normally 2½ in. thick by 25½ in. wide by 10½ ft. long and weighing about 2100 lb.,* is first put through a milling machine to round off the four corners, thus eliminating the fish-tail spreading at the ends of the rolled bars. It is then possible to set guides closer during subsequent rolling operations and this tight mechanical control minimizes edgewise camber or snaking of the strip.

Breakdown is in a heavy two-high nonreversing stand built by Farrel-Birmingham Co., served by roller tables, returns, and bypasses and completely mechanized with control from two desks, one on either side of the stand. Giant clock dials mounted on the screwdown mechanism indicate visually the roller openings; in addition "selsyn" units on the entry control desk indicate openings of 0.001 in. Power devices for quick roll changing are installed. In this mill, and its annealing furnace operated in correct sequence, the 2½-in. bar is reduced to 0.40 in. thick and correspondingly lengthened. (Annealing practices and furnaces will be described in detail in a subsequent article in *Metal Progress*.)

As is seen in the general view of the mill, Fig. 1, the mill has the usual modern handling equipment — overhead cranes, roller tables (by Mathews Conveyer Co.), transfer chains, turnover cradles, lift trucks, all designed to prevent damage to finished surfaces en route. The vacuum cup for handling (Fig. 3) will appeal to many readers as unique. Handling a one-ton bar at entrance and delivery tables of the breakdown mill would at first sight appear to be quite a job. The machine one actually sees was made by Wean Engineering Co. and comprises a series of tentacles which reach down, their suction ends press onto the bar, a vacuum is established under each, and the suction holds the bar while it is being placed wherever desired. Breaking the vacuum then releases the bar. The octopus behind the tentacles is a vacuum line, operating at about half the atmospheric pressure. The area inside the rubber ring of each tentacle may be 50 sq.in., thus giving a lifting capacity of 350 lb. for each cup. The span of each gantry is sufficient to handle partially rolled bars up to 64 ft. long. Cups not in action at any one lift may be cut off the vacuum line either locally or from the control desk.

Bar Surface Milling — The original outside surface of the cast bar is rough and may contain imperfections. The rolled bar is first flattened and then passed through two large milling machines which completely remove the surfaces, both top and bottom. An opportunity is provided at this stage for careful visual inspection. Chips are removed by suction to an overhead hopper of the dual type (to avoid mixing of scrap when alloys are being changed).

From the flow sheet, Fig. 2, it will be seen that the subsequent equipment in the mill is based on cold reduction in two identical four-high mills,

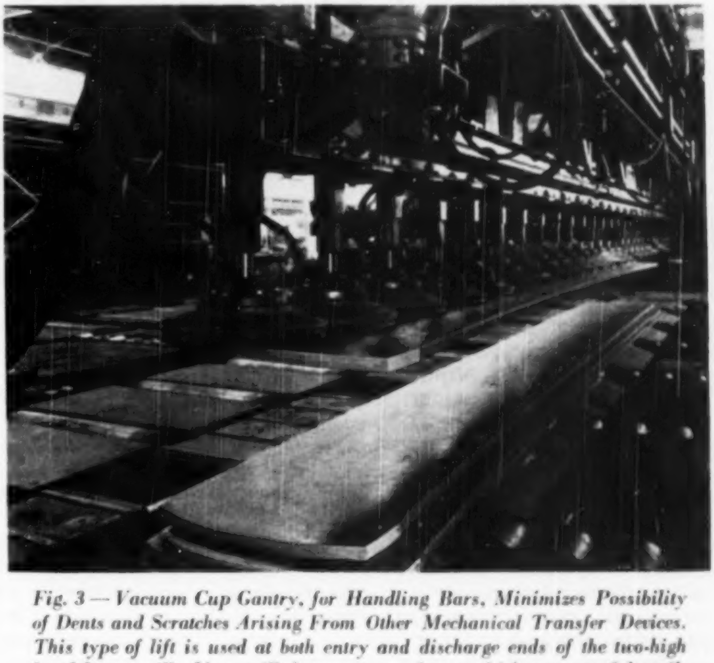


Fig. 3 — Vacuum Cup Gantry, for Handling Bars, Minimizes Possibility of Dents and Scratches Arising From Other Mechanical Transfer Devices. This type of lift is used at both entry and discharge ends of the two-high breakdown mill. Note milled corners on bars, which prevent fish tailing during rolling and permit closer setting of guides at roll stands

*Maximum size of bar that can be handled in the mill is 2½ in. thick by 28 in. wide by 10½ ft. long weighing about 2500 lb.

built by United Engineering & Foundry Co. Spacing between work rolls in these mills is kept constantly uniform by photo-electric controls, which compensate for varying temperatures of rolls and housings. Coil handling systems, made by Logan Co., are highly developed for sure and prompt handling, despite variations in width, gage and weight. The relative amount of work done on each mill will depend on metallurgical and size requirements and on the balance of economical production for the orders in process. The first (or "rundown") mill can produce strip 0.050 in. thick and uses a Logan upcoiler at the discharge end; the second or "finishing" mill has a reel for metal down to 0.011 in. thick. Light gages are normally given a surface pinch-pass in a third mill, noted on the flow sheet as a "Four-High Light Gage Finisher".

Pickling units are of Metalwash Machinery Co.'s completely automatic design. They are about 150 ft. long, operate at high speed (up to 600 ft. per min.) and consist of a series of sulphuric acid, bichromate, cold water, hot water, and soap solution tanks (all utilizing pressure sprays) and a final hot air dryer. Final cold rolling for temper and surface (either before or after slitting to proper width), edge trimming and inspection ready the brass for shipment. Various routes, depending on width and thickness, can easily be taken. All roll stands are designed to produce exceptionally flat brass strip and sheet, and to minimize crown and end-to-end variation.

Final production can, therefore, be brass plate or strip in any thickness below 2 in. down to 0.010 in., in any width below 28 in. The length is, of course, in inverse proportion to the area of the strip's cross section, and the weight in direct proportion to finished width. For example, a coiled strip 2 in. wide by 0.010 in. thick will be more than 1/3 mile long and weigh about 140 lb.

Nickel and Chromium Plating Compared

By Jerome L. Bleiweis
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THE USE of hard chromium plating for building up worn or otherwise undersize parts is well known. Chromium deposits have a hardness of from 60 to 70 on the Rockwell C scale and where the combination of extreme hardness, excellent wear resistance, and low frictional characteristics is required, chromium is the best choice. However, there are several practical difficulties in the use of hard chromium:

1. The "throwing power" of chromium plating baths (that is, the ability of the bath to cover recessed areas as rapidly as areas closer to the anodes) is very poor. Throwing power measurements for chromium, determined by the Haring cell method, yield results varying from an exceptional −15% to lower than −100%, as compared with nickel plating bath values of as high as +10% but usually at about 0%. The more negative values indicate poorer throwing power. In practical operating terms this means that hard chromium deposits are considerably thicker on areas closer to the anodes than on areas which are recessed or farther from the anodes. As a consequence, special "conforming" anodes must be constructed for each chromium plating job to minimize this effect or the deposit thickness must be considerably heavier than required, with a grinding operation subsequently employed to restore dimensions.

2. The current efficiency (ratio of current producing chromium to total current used to produce cathodic products) of chromium plating solutions is very low. In a solution containing 33.3 oz. per gal. of CrO_3 and 0.33 oz. per gal. of H_2SO_4, at a current density of 288 amp. per sq.ft. and 130° F., the current efficiency is 16.4%, and at 144 amp. per sq.ft. and 130° F. the current efficiency is as low as 10.4%. Almost 90% of the current used goes toward the evolution of hydrogen. For bright nickel, current efficiencies are 95% or higher.

3. Another factor related to the deposition rate of chromium is the hexavalent nature of

chromium. In chromium plating solutions, six electrons are required to deposit one atom of chromium, whereas only two are required to deposit an atom of nickel.

4. The deposition rate of chromium at high speeds is 0.001 in. per hr., and frequently it is much lower. Nickel may be deposited from modern high-speed bright plating baths at rates of 0.004 in. per hr. or higher. At 75 amp. per sq.ft. and 145° F., nickel is deposited at the rate of 0.004 in. per hr. At 145° F., 0.001 in. of chromium per hr. is deposited at about 350 amp. per sq.ft., and at 130° F. about 300 amp. per sq.ft. is required to deposit 0.001 in. per hr.

It is evident from the above that considerable economy of operation may be effected by using nickel in place of chromium where possible. It is also evident that power installations need not be so large for nickel and that the time required to attain the same thickness will be almost five times as great for chromium as for nickel. Furthermore, because of the superior throwing power of nickel plating solutions, less overplating and subsequent grinding will be required.

Although nickel deposited from hard nickel or bright nickel solutions is not so hard as hard chromium, nickel is adequate for many purposes. Comparative hardness values are: bright or hard nickel 350 to 500 Vickers and hard chromium 850 to 1200 Vickers.

Conditions of Nickel Plating

Two types of bath may be used for obtaining hard nickel deposits.

Hard Nickel Type — Nickel sulphate 24 oz. per gal., ammonium chloride 3.5 oz. per gal., and boric acid 4.0 oz. per gal. The bath is operated at an electrometric pH of 5.0 to 5.4, temperature of 120 to 140° F. and current density of 25 to 50 amp. per sq.ft.

Bright Nickel Type — Nickel sulphate 48 oz. per gal., nickel chloride 8 oz. per gal., boric acid 5.5 oz. per gal., and proprietary brighteners as directed. This bath is operated at a pH of 4.0 to 4.5 for optimum hardness, temperature of 150 to 155° F., current density 75 to 100 amp. per sq.ft.

The first bath is specifically for hard nickel plating and will produce smooth, dense, but not bright plates. The second is a proprietary bright nickel plating solution whose use would not be limited solely to hard nickel plating. By appropriate changes in some of the operating conditions, this bath may be used for hard nickel or commercial bright nickel plating. This more expansive utility is a factor in its favor over the specifically hard nickel type of solution, particularly where a combination of commercial bright nickel and hard nickel would be required to keep the bath running at capacity. The most suitable type of proprietary bright nickel to use for hard nickel purposes — and general-purpose bright nickel too — is the type employing a metallic zinc brightener plus a sulphonic or naphthalene-sulphonic acid derivative addition agent.

At pH values of 4.0 or higher this type of bath will yield extremely hard deposits, whereas at a pH of less than 3.0, more ductile, softer deposits will be obtained. Where a bright nickel plating solution is used for deposition of hard nickel, more of the embrittling organic and inorganic impurities may be tolerated. As a matter of fact, precisely those embrittling impurities that users of bright nickel go to great lengths to remove in order to get softer, more ductile bright nickel deposits, act as extra addition agents making for greater hardness where the application is specifically hardness or build-up. However, relatively satisfactory hardness control may be achieved by control of pH.

Procedure

Presuming the use of the bright nickel plating solution described above, the procedure for plating steel objects would be as follows:

1. Using a heavy-duty alkaline cleaner, clean the work cathodically at a tank voltage of about 6. The cleaning period will be from 30 to 90 sec.
2. Reverse the potential across the tank and clean anodically for 15 to 45 sec.
3. Rinse the work in cold water.
4. Pickle in 10 to 50% muriatic acid.
5. Rinse in cold water.
6. Nickel plate.

For the maximum plating rate, the work should be agitated. This is best accomplished by driving the work rod back and forth, parallel or perpendicular to the anodes, 30 to 45 cycles per min.

On worn shafts or other uncomplicated shapes the plating rate should be calculated, and the plating allowed to proceed for that length of time during which the correct amount of nickel, or a few ten thousandths more than the correct amount, will be deposited. With experience and proper control, an uncanny accuracy can be achieved. It has been the author's experience on several occasions, where the application involved was sufficiently flexible, to deposit exactly the required thickness with almost no "out of roundness". Where overplating is required, the plate may be readily ground or machined to dimensions.

An added, and sometimes desirable, feature achieved by using bright nickel for build-up purposes is that the decorative quality of the work is enhanced. On many parts where several thou-

sandths of plate is applied, the appearance of the plated work very closely resembles highly buffed metal. This apparently minor detail has frequently been very important in the final product.

Applications

There are numerous applications for bright nickel plating solution to provide fairly hard deposits on undersized or worn objects. Shafts and rotors may be built up in this manner. In electroforming, bright or dull nickel is frequently used after an initial deposit of acid copper.

On complicated shapes, nickel has a particularly interesting application. The author has had occasion to use nickel to build up inner bearing surfaces of sewing machine shuttles where it was practically impossible to get chromium to deposit in the recess in which the bearing surface was set. Frequently on such complicated shapes, even when chromium can be deposited, expensive machining operations are eliminated by using nickel.

An interesting application making use of the hardness of bright nickel is in the production of decorative surfaces that will not scratch easily. For example, a highly polished gold plated buckle will be more resistant to scratching if the gold is "flashed" over a bright hard nickel undercoat than if it is deposited directly on the brass. Combination nickel and chromium deposits may be used where the amount of metal to be deposited is excessive and where some surface characteristic of hard chromium is required. Thus a shaft may be built up by depositing 0.020 in. of nickel on the diameter followed by 0.010 in. of hard chromium.

Electrodeposits of either nickel or chromium, besides being used for increasing dimensions, may provide protection against corrosion, particularly on steels. For this purpose, nickel is considerably superior to chromium. Bright nickel that is plated out of modern high-speed baths will be pore-free at about 0.0005 in. of nickel and will not crack or peel at much greater thicknesses. Chromium, on the other hand, deposits continuously, though not pore-free, until the deposit is about 0.00002 in. thick. After this, the stresses in the deposit cause the formation of fine cracks which extend down to the base metal. This phenomenon becomes more pronounced as the thickness increases; the cracks increase in number, with a consequent decrease in corrosion resistance. As the plating progresses still further, metal begins to bridge over the old cracks; new cracks then form and extend down to the already deposited chromium rather than to the base metal. The thickness required for a continuous pore-free chromium plate is considerably in excess of the corresponding nickel requirement.

Stripping and Replating

Where replating is necessary the procedure applicable for chromium is considerably less critical than the one for nickel. Old chromium may be stripped from steel very easily and with absolutely no attack on the steel by making the chromium plated piece the anode in almost any alkaline solution at about 6 volts. For example, 6 oz. per gal. of sodium hydroxide or sodium carbonate, warm or at room temperature, is an inexpensive and easily operated anodic stripping solution for chromium plate. Concentrated muriatic acid may be used too, but will etch the steel surface.

Nickel, on the other hand, especially where the deposits are heavy, does not strip as cleanly as does chromium. A conventional stripping solution for nickel from steel is: sulphuric acid 5 pints per gal. and glycerine 1 oz. per gal. The solution is used at room temperature, the nickel plated work the anode, and the bath voltage at 6. The surface is etched and frequently pitted. A simple immersion procedure for stripping nickel from steel involves the use of fuming nitric acid as the stripping medium. Although little etching occurs in a fresh water-free bath, the solution is difficult to control and hazardous to use.

Nickel will not deposit very adherently on a previously deposited nickel coating; old plate must be completely stripped before replating. However, by suitably activating a previously deposited chromium coating, more chromium may be plated on the old coating without complete stripping.

Summary

To sum up, the comparative merits of chromium versus bright nickel utilized as hard deposits to build up worn or undersized parts are:

1. Chromium is considerably harder than bright nickel.
2. Chromium has a much lower coefficient of friction than bright nickel.
3. Wear resistance of chromium is superior to that of bright nickel.
4. Bright nickel deposits are far more economical to apply than chromium deposits.
5. The plating rate for bright nickel is four to five times the chromium plating rate.
6. Throwing power of bright nickel is superior to chromium throwing power.
7. Bright nickel installations will be smaller than chromium installations of like capacity.
8. Chromium is stripped more easily and cleanly than bright nickel.
9. Chromium may be plated successfully on old chromium, but nickel requires stripping.

Effect of 1150° F. Aging on Cr-Mo Steel Castings (2.5 to 9% Cr)

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IN THE LAST DECADE there has been a considerable increase in the number of standard alloy steels, some "tailored" to meet the demands of a single important consumer or industry. That trend has also been observed in the high-chromium steels for high-temperature service. Particularly is this true of wrought steels. For example, Claude L. Clark, of Timken's organization, describes (in *Metal Progress* for December 1946) no less than six varieties of 5% chromium steels and five varieties in the higher range up to 10% chromium, all being based on different contents of molybdenum and silicon, with or without titanium or columbium to improve weldability. In addition to the higher-chromium compositions, considerable quantities of "corrosion resisting" steel containing about 2½% chromium have been manufactured.

Much of the Cr-Mo steel is consumed by petroleum refineries, and from them has come a demand for castings (pipe fittings, valves and pump parts) which matched the physical and chemical properties of the wrought material and which could be safely welded thereto. In view of the likelihood that cast structure and wrought structure would have measurable differences, we in Crane Co.'s research laboratories have systematically studied the Fe-Cr-Mo-C system (and, more recently, that system plus nickel up to 2%). Rather brief accounts of this extensive work have been published by the present authors in ⊕ *Transactions* (Vol. 34 for 1945, p. 589, and Vol. 37 for 1946, p. 360), confined almost exclusively to room temperature mechanical properties of keel blocks and cast 2-in. Tees after the following heat treatment: Normalize from 1750° F., air quench from 1550° F., draw at 1250° F. The general conclusion was that a carbon content of 0.15 to 0.20% was sufficiently high to meet the tensile and impact specifications of the American Petroleum Institute in the important chromium-molybdenum analyses,* that welded joints in such castings (not preheated) contained no dangerously hard or corrodible transition zones, and that stress relief at 1300° F. ironed out the hardness variations across the weld almost completely.

The second *Transactions* article mentioned above paralleled the data for these chromium-molybdenum steels after the addition of nickel. These analyses are very interesting metallurgically, in that the nickel increases the strength properties of well-balanced Cr-Mo castings (heat treated as noted above) without reducing ductility or impact resistance — a feature that is magnified as the air-quenching rate is progressively slowed down. Likewise, the hardness of stress-relieved welds (made with standard 5% Cr-Mo electrodes) is practically the same as the base metal.

The above publications related to steels whose history approximated the production heat treatments of the foundry and fabricator. Since the castings are generally used in high-temperature service, it is obvious that long stays at operating temperatures (up to 1150° F.) may have a con-

*Two of the common specifications are as follows:

	5% Cr	9% Cr
Carbon	0.15 to 0.30%	0.15 to 0.30%
Silicon	0.20 to 1.25%	0.20 to 1.25%
Manganese	0.45 to 0.75%	0.45 to 0.75%
Sulphur	0.06% max.	0.06% max.
Phosphorus	0.05% max.	0.05% max.
Chromium	4.0 to 6.0%	8.0 to 10%
Molybdenum	0.40 to 0.65%	0.75 to 1.50%

Required mechanical properties for both:

Tensile strength	90,000 psi. min.
Yield point	65,000 psi. min.
Elongation in 2 in.	18% min.
Reduction of area	30% min.
Charpy impact (70° F.)	15 ft-lb. min.
Brinell hardness	235 max.

siderable effect on the properties — even if all allowance is made for the well-known sluggish microstructural changes in the chromium-molybdenum steels. We have had an opportunity to investigate this point, and the following notes summarize the findings.

Some selected compositions from the two series of steels were subjected to a high-temperature aging at 1150° F. for 2000 hr. Samples were air cooled from the aging heat. Prior to such aging, all of them were heat treated by normalizing from 1750° F., air quenching from 1550° F., and drawing at 1250° F. Aged steels were tested for tensile properties in standard 0.505-in. diameter, 2-in. gage test bar, and Charpy impact resistance of standard 10-mm. square test bar with a keyhole notch. Test data on aged steels thus assembled (average values of duplicate tests) are recorded in the table in the *italic* lines. Chemical analyses and similar mechanical properties of the identical steels, prior to aging, were borrowed from the former two papers and are also included as lines set in roman type.

Mechanical Properties

The table thus contains two sets of test data, one set in roman type obtained before and the other set in *italic* type after the high-temperature aging treatment at 1150° F., so that direct comparisons can be made. Moreover, it represents two groups of steels — one nickel-free, and the other containing 2% of nickel. Each group is divided into four chromium levels (2.5%, 5%, 7% and 9% Cr) and each chromium level consists of three carbon contents (under 0.1%, about 0.15% and about 0.30%). It also may be noted that the same serial numbers have been maintained in the table as were used in the two previous publications.

A study of the recorded data indicates that high-temperature aging (service) with some few exceptions reduces breaking strength,* tensile strength and yield point. This effect is more pronounced in the nickel-bearing steels than in the nickel-free steels. However, in the low-carbon, nickel-free compositions, these properties are almost unaffected (Serial No. 7 and 24) or even are slightly improved (Serial No. 47 and 68).

Proportional limit is reduced in these steels when the yield point is reduced considerably (as for example, in Serial No. 49, 71, 15 and 33). In most cases where the yield point is decreased only moderately, particularly in the nickel-bearing alloys (as in Serial No. 3, 9, 27 and 36), or even increased (as in Serial No. 47 and 68), the proportional limit also increases.

*Breaking load divided by area of the fracture.

Elongation and reduction of area are increased by high-temperature aging in all of the nickel-bearing compositions except two (Serial No. 27 and 36), both of which have basically very low ductility. In the two lower-chromium, low-carbon steels (Serial No. 3 and 12), the increase of the reduction of area after aging is very slight. Elongation of the steels in the nickel-free set is either unaffected or has a tendency to increase (except for two — Serial No. 47 and 49). Reduction of area for the same set, on the other hand, is decreased in all instances but two: Serial No. 50 and 71.

Yield ratio in most of the steels is either affected very slightly or is decreased. Only in two instances (Serial No. 47 and 68) did the 2000 hr. at 1150° F. increase the yield ratio to a rather appreciable extent.

Hardness, as should be expected, is always reduced. Moreover, the loss is more pronounced in higher carbon analyses and in nickel-bearing compositions.

Impact tests of all steels were made at room temperature before and after aging. In addition, all steels were also tested *(a)* at −25° F. before aging and *(b)* at 1000° F. after aging. For the sake of completeness, the subzero and high-temperature test data are included in the table. However, since no comparison can be made for these properties between unaged versus aged conditions, appraisals must be confined to the room temperature impact resistance only. It turns out that Charpy impact resistance (test samples at room temperature) is either unaffected within experimental error by high-temperature aging or is reduced, in all steels but three (Serial No. 11, 12 and 21).

Microstructure

Metallographic characteristics of these steels were discussed rather completely in the previous publications. The present study is thus confined to four steels only. All contain about 5% chromium; two of them are nickel-free, whereas the other two contain about 2% nickel. Both low-carbon (0.07% C max.) and high-carbon (0.27 to 0.32% C) contents are represented in each set of accompanying micrographs. It is believed that they present a fairly representative picture of the effect of aging at 1150° F. on the structural characteristics of all of the steels we have studied (chromium up to 9%, molybdenum up to 1.5%, carbon up to 0.30%, nickel up to 2.0%).

As should be expected, high-temperature aging always promoted spheroidization of carbide constituents beyond that degree obtained by drawing

Mechanical Properties of Chromium-Molybdenum Steel Castings

Standard Heat Treatment: Normalize at 1750° F., Air Quench From 1550° F., Draw at 1250° F.
Properties in Italics Are for Standard Heat Treatment Plus Aging 2000 Hr. at 1150° F.

Serial No.	Chemical Analysis*				Tensile Properties							Vickers Hardness	Charpy Impact		
	Cr	Mo	C	Ni	Breaking Str. †	Tensile Str.	Yield Point	Yield Ratio	Proportional Limit	Elongation in 2 In.	Reduction of Area		−25° F.	+70° F.	+1000° F.
2.5% Cr, 0.5% Mo					**Chromium-Molybdenum Steel Castings Without Nickel**										
7	2.51	0.51	0.02	—	85,000	53,400	30,500	0.57	25,500	42.3	70.5	137	28.0	47.0	
					84,700	*50,300*	*28,500*	*0.57*	*25,000*	*39.0*	*58.0*	*135*		*44.0*	*48.0*
10	2.75	0.60	0.14	—	159,000	101,000	70,000	0.69	56,700	24.0	51.0	220	8.3	15.3	
					121,400	*88,300*	*58,500*	*0.67*	*42,500*	*24.0*	*34.0*	*189*		*14.5*	*27.0*
11	2.71	0.52	0.24	—	160,000	112,000	80,200	0.72	64,900	18.8	48.8	280	1.5	4.8	
					129,300	*97,500*	*58,800*	*0.52*	*43,500*	*24.5*	*35.0*	*210*		*20.0*	*20.5*
5% Cr, 0.5% Mo															
24	4.88	0.50	0.02	—	—	58,500	34,000	0.59	24,500	35.8	61.5	155	27.0	47.5	
					99,000	*56,000*	*31,300*	*0.56*	*24,000*	*39.0*	*56.0*	*142*		*30.0*	*59.0*
28	5.13	0.52	0.15	—	184,000	106,600	82,300	0.77	72,100	23.0	55.8	250	16.5	30.5	
					129,300	*88,800*	*59,500*	*0.67*	*55,500*	*23.5*	*42.0*	*197*		*20.3*	*34.0*
30	5.44	0.51	0.32	—	171,200	116,600	83,600	0.77	73,100	20.3	52.8	295	11.3	22.0	
					150,300	*94,800*	*36,000*	*0.38*	*30,000*	*25.5*	*47.5*	*207*		*12.0*	*27.5*
7% Cr, 1% Mo															
47	7.01	1.03	0.03	—	122,000	63,000	36,500	0.58	26,500	41.8	65.5	169	30.0	44.3	
					127,600	*64,300*	*57,300*	*0.89*	*50,500*	*29.5*	*58.0*	*155*		*20.3*	*49.3*
49	7.03	1.12	0.17	—	182,000	107,000	79,300	0.74	62,800	33.0	52.3	275	17.5	25.3	
					148,500	*93,300*	*47,000*	*0.50*	*38,000*	*27.0*	*48.0*	*200*		*18.3*	*24.8*
50	7.66	1.08	0.34	—	167,000	117,400	83,300	0.71	64,400	19.3	35.8	290	4.0	9.5	
					158,300	*95,500*	*47,800*	*0.50*	*45,500*	*28.0*	*51.5*	*201*		*13.3*	*31.5*
9% Cr, 1.5% Mo															
68	8.76	1.65	0.02	—	98,000	66,800	39,500	0.59	27,500	29.0	64.0	177	2.5	30.5	
					97,300	*71,300*	*62,000*	*0.87*	*56,000*	*28.5*	*44.0*	*167*		*23.5*	*38.8*
70	8.78	1.80	0.14	—	169,500	96,300	62,600	0.65	47,800	24.8	48.3	290	1.5	21.5	
					138,500	*87,400*	*63,700*	*0.73*	*46,700*	*28.0*	*47.5*	*186*		*11.8*	*25.3*
71	9.08	1.62	0.26	—	170,000	109,100	78,600	0.72	65,800	21.3	37.8	295	3.5	18.0	
					158,100	*98,800*	*34,800*	*0.36*	*28,500*	*28.0*	*50.5*	*199*		*15.5*	*31.5*
2.5% Cr, 0.5% Mo, 2% Ni					**Chromium-Molybdenum-Nickel Steel Castings**										
3	3.09	0.53	0.05	1.77	135,900	88,700	60,600	0.68	38,400	27.8	65.8	207	32.3	41.5	
					159,000	*77,600*	*53,600*	*0.69*	*52,600*	*33.5*	*68.5*	*167*		*41.0*	*50.3*
6	2.81	0.60	0.09	2.00	210,000	148,000	123,300	0.83	88,800	14.0	45.3	327	2.0	12.8	
					198,600	*97,000*	*76,800*	*0.79*	*71,500*	*24.5*	*62.0*	*215*		*8.3*	*30.0*
9	2.59	0.58	0.22	2.59	202,000	165,500	124,000	0.75	64,800	11.5	26.0	378	4.0	8.3	
					167,500	*106,800*	*84,800*	*0.79*	*75,000*	*22.0*	*48.5*	*238*		*9.3*	*26.3*
5% Cr, 0.5% Mo, 2% Ni															
12	4.90	0.53	0.07	1.70	196,200	116,400	103,500	0.89	82,800	19.0	61.8	264	7.0	19.0	
					160,900	*86,500*	*63,500*	*0.74*	*62,500*	*31.5*	*63.0*	*185*		*24.8*	*43.8*
15	5.10	0.57	0.14	1.98	245,800	151,400	112,500	0.74	88,600	15.0	46.8	335	5.5	9.0	
					157,900	*101,300*	*79,800*	*0.79*	*74,000*	*25.5*	*50.0*	*224*		*5.3*	*30.3*
18	5.39	0.72	0.27	2.18	188,000	159,100	127,500	0.80	101,200	10.5	21.5	353	3.0	5.3	
					143,800	*109,800*	*84,500*	*0.78*	*74,000*	*20.0*	*30.0*	*241*		*5.8*	*25.3*
7% Cr, 1% Mo, 2% Ni															
21	6.70	1.03	0.06	1.98	200,500	141,800	109,300	0.77	59,800	16.0	50.5	309	16.3	22.8	
					152,600	*83,000*	*62,500*	*0.76*	*58,500*	*32.5*	*62.5*	*183*		*37.0*	*47.5*
24	7.35	1.00	0.12	1.97	216,700	143,600	115,300	0.81	53,700	16.3	50.0	303	13.3	26.0	
					164,700	*101,300*	*80,000*	*0.79*	*76,000*	*26.5*	*55.5*	*224*		—	—
27	7.02	1.18	0.31	2.00	148,200	138,750	108,000	0.78	62,000	6.0	7.0	307	1.8	2.5	
					118,200	*112,300*	*92,500*	*0.83*	*85,000*	*6.5*	*5.8*	*260*		*2.3*	*23.0*
9% Cr, 1.5% Mo, 2% Ni															
30	8.96	1.82	0.05	1.94	209,300	133,100	108,500	0.85	67,500	18.3	44.8	293	14.8	19.8	
					171,900	*96,000*	*65,000*	*0.68*	*50,500*	*27.0*	*56.5*	*207*		*20.0*	*38.3*
33	10.88	1.40	0.16	2.13	201,500	137,400	106,800	0.78	67,000	16.0	49.5	298	12.3	14.0	
					175,500	*104,800*	*73,300*	*0.70*	*50,000*	*24.5*	*55.5*	*224*		*13.5*	*37.3*
36	8.90	1.40	0.23	2.12	171,500	136,300	108,500	0.80	68,100	7.3	10.0	297	3.0	5.0	
					125,300	*116,300*	*96,500*	*0.83*	*80,000*	*7.0*	*7.0*	*260*		*4.0*	*21.5*

*Complete analyses are contained in articles in *Transactions*. Sulphur <0.030%; phosphorus <0.030%; silicon 0.60 to 0.90%; manganese 0.45 to 0.80%. †Breaking load divided by area of the fracture.

All samples etched in nital and magnified 500 diameters. Prior heat treatment of all samples: Normalized at 1750° F., air quenched from 1550° F., drawn at 1250° F. Aging treatment: 2000 hr. at 1150° F., air cooled

Drawn, Not Aged **Aged at 1150° F.**

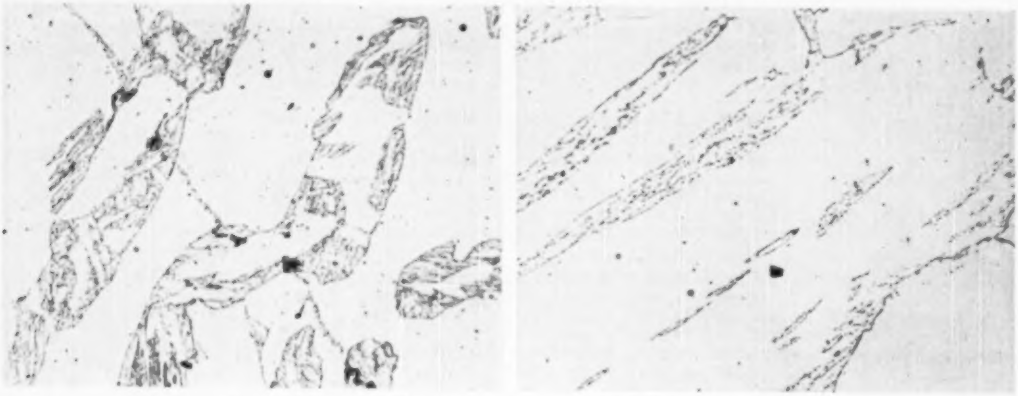


Fig. 1 — Serial No. 24, Nominally 5% Cr, 0.5% Mo, 0.02% C

Drawn, Not Aged Aged at 1150° F.

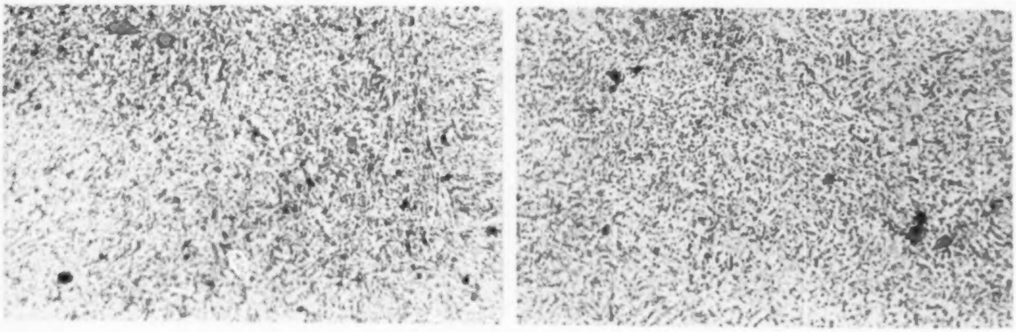


Fig. 2 — Serial No. 30, Nominally 5% Cr, 0.5% Mo, 0.32% C

Drawn, Not Aged Aged at 1150° F.

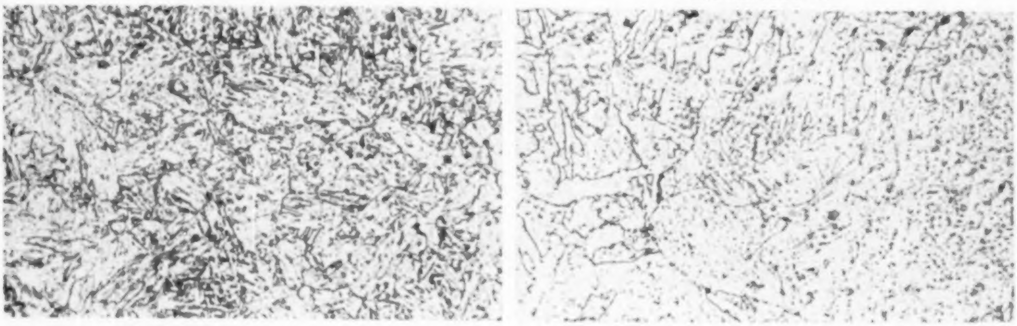
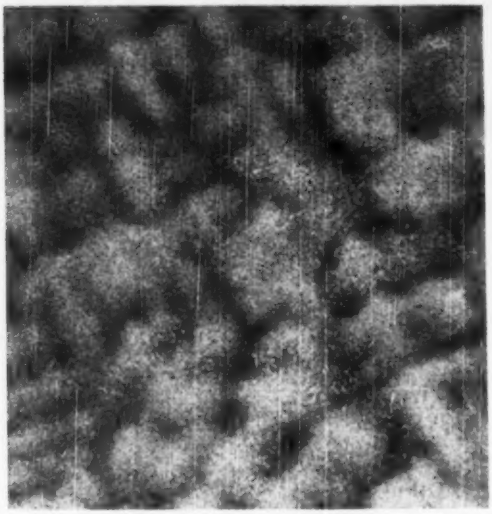
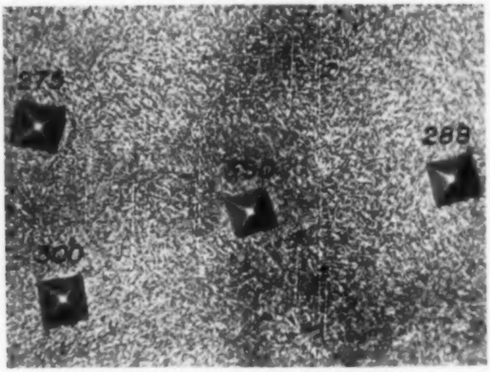


Fig. 3 — Serial No. 12, Nominally 5% Cr, 0.5% Mo, 1.7% Ni, 0.07% C

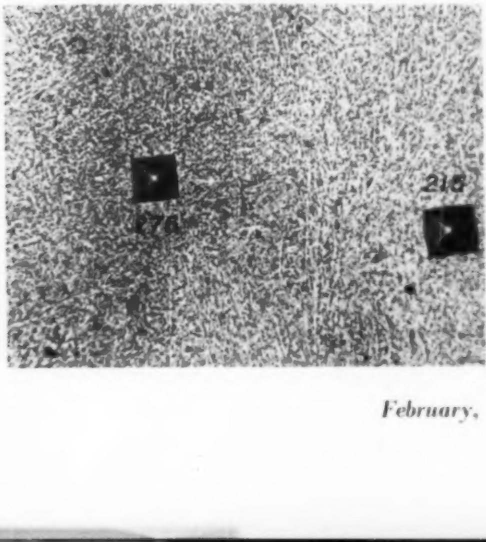
Segregation as Revealed by Nital; 100 ×



Drawn, Not Aged



Aged at 1150° F.



at 1250° F. prior to such aging. Moreover, in nickel-free steels (Fig. 1 and 2), this process progressed further than in the nickel-bearing ones (Fig. 3 and 4). This is in accord with our previous observations and with the remarks by Krivobok when discussing our 1946 paper. At that time it was pointed out that nickel-bearing steels are more sluggish thermally, and more subject to persistent dendritic segregations than similar compositions containing no nickel. The tendency for dendritic segregation is particularly well illustrated in Fig. 4; segregation was not eliminated by the triple heat treatment and persists even after 2000 hr. aging at 1150° F. Microhardness tests indicate that the dark, carbon-rich portions are considerably harder than the light, carbon-poor ones. This difference in hardness is reduced but not eliminated by aging 2000 hr. at 1150° F.

Conclusion

In conclusion, it might be stated that these limited experiments may be of some interest because the aging temperature of 1150° F. is within the range of those frequently used in the oil refining processes, and the steels are modifications of those used for refinery service. An exposure to that temperature over a period of 2000 hr. resulted in spheroidization of the carbide constituent, which in turn reduced strength, yield point and hardness, particularly in the low-carbon compositions. The static, room-temperature ductility (particularly reduction of area) and impact resistance of most of the nickel-free compositions were likewise reduced by the long stay at high temperature. Static ductility of the nickel-bearing steels, on the other hand, was almost universally increased, while the impact resistance usually remained unchanged. Comparison of the Charpy impact values given in the table for either aged or unaged steels with and without nickel indicates that the chromium-molybdenum alloys without nickel usually give considerably higher results when tested at −25° F. or at +70° F., and give similar results when tested at 1000° F.

An improvement in properties does not necessarily mean that nickel-bearing compositions should be recommended in preference to the nickel-free ones. As we have previously pointed out, additions of nickel make steels of this type more thermally sluggish. This, in turn, may present greater problems with regard to cracking during heat treating and welding.

Fig. 4 — Serial No. 18, Nominally 5% Cr, 0.5% Mo, 2.2% Ni, 0.27% C. Effects of segregation on microstructure and microhardness

The Organization of Iron and Steel Research in France

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France has a new organization for ferrous metallurgical research, known as the Institut de Recherches de la Sidérurgie (*IRSID*). *Like the British Iron and Steel Research Association and the* Kaiser Wilhelm Institut fuer Eisenforschung *in Germany, IRSID will have its own laboratories and will do for the steel industry what private companies cannot reasonably undertake alone. The description given here has been extracted from an article by Mr. Delbart in* Revue de Métallurgie.

SCIENTIFIC and technical research in the French iron industry goes back to an early date, and it is necessary only to recall the names of Osmond, Heroult, Martin, Charpy, LeChatelier, L. Guillet . . . and those of a younger generation — Portevin, Chevenard, Chaudron, Perrin and many others — to be convinced of French vigor and individuality in this branch of metallurgical research. Sometimes these scholars have made their discoveries quite alone, of their own initiative, with limited material means. Often research has been undertaken and brought to a happy conclusion in factory laboratories, and always with the motive of private initiative.

But, as Louis de Broglie comments: "If the great discoveries have often been the work of an individual, the development of their consequences and their application require the coordination of many workers." Collective research has today become a necessity. Hence, the decision to create an institute of ferrous metallurgical research in France. This, far from eliminating free research, will encourage it by opening the windows wide to outside influences, by forcing the avoidance of all dogmatism and by assuring connections formerly nonexistent.

Iron research in France began to be organized in 1939 under the sponsorship of the *Comité des Forges* over which M. de Wendel presided at the time. *Commissions d'Ingenieurs* were created by this committee. These engineering commissions, 14 in number, were composed of specialists who were united under the chairmanship of one among them, chosen for his particular competence. Their goal was to study problems bearing on their specialty, exchange opinion, and pool experiments.

These commissions were as follows: coke, Thomas blast furnaces, blast furnaces other than Thomas, Thomas steelworks, Martin steelworks, electrical steelworks, rolling mills (East and North), rolling mills (Central), heat treatments (Central), heat treatments (East and North), flat rolled products, steel castings, fuels, and refractory products.

Each of these commissions met several times and some showed signs of a promising vitality when the war interrupted, and the occupation put a stop to everything. They were reorganized in December 1945, except for the commission on steel castings, which was replaced by the recently organized *Centre Technique de la Fonderie*. Georges Grenier became the general secretary of these commissions. Subjects treated are of a technical nature, but technique always poses incidentally some scientific problems when investigation is pushed a little further.

The corporate body capable of helping the engineering commissions — whether by problems for laboratory study set by the commissions or by

plant research on an industrial scale — did not exist, but the project of its creation was in the air by 1938, the year when M. Lambert-Ribot, at the instigation of M. Portevin, secured from the board of directors of the *Comité des Forges* the financial possibility for such an organization, through a tax on iron and steel tonnage.

Then came the war and the occupation . . . Nothing happened until 1943. But a handful of men who kept their confidence in the fate of France were preparing for the future. Under the sponsorship of J. Aubrun, the *Commission d'Etudes Scientifiques et Techniques* (CEST), directed at first by M. Taffanel and later by H. Malcor, commissioned the engineer Jean Rist with studies relative to creation of a laboratory on iron research. Jean Rist accordingly drew up organizational plans and rough drafts for the laboratories. His report was approved; it became the basis for actual realization. Jean Rist in 1944 rejoined the French forces of the Interior, and was killed the 21st of August in a rear-guard action; in memory of his creative work and his sacrifice, the name of Jean Rist was given, the 19th of June, 1948, to the first building of the future laboratories of the *Institut de Recherches de la Sidérurgie* (IRSID), to be put up at Saint-Germain-en-Laye.

Organizational Plan of IRSID

According to its organizational plan, IRSID is controlled equally by the Ministry of Industry and Commerce and by the State Secretariat for Economic Affairs. It has a board of directors which defines general policy and controls financial management.

Discussion of the general research program is by a *Conseil Scientifique et Technique* (COST), presided over by H. Malcor. Subjects for study are examined in special commissions, of which the main one is the scientific commission, presided over by M. Chevenard, member of the Institute.

The director, assisted by a scientific counsellor, Albert Portevin, member of the Institute, administers, organizes and coordinates.

Connections with industry are normally guaranteed by the intermediacy of the engineering commissions; contacts with the universities, by the scientific commission which is composed of seven university professors. Naturally, direct relations have also been established with industry and the universities by the various staff members of IRSID.

Outside services comprise: ores, with the testing station at Saulnes; coke and blast furnace, with the bureau at Longwy; and steelworks.

Services are divided, at the moment, as follows: physics and statistics, metallography and mechanical testing, chemistry and physical chemistry, general services (factory workshop — electrical services, apparatus), administrative and accounting, and documentation and library.

Temporary bureaus and laboratories were set up on an estate in the province of Saint-Léger, at Saint-Germain-en-Laye, taken over by IRSID in July of 1946. The laboratories, very limited at the moment, will be expanded when the Jean Rist building is completed, probably at the end of 1949, but will not be fully developed until after the completion of the scientific laboratories, which will probably be in 1951.

Outside of its activity proper, IRSID has established commissions in common with neighboring industries, coal mines, the foundry, painting (rustproof coating), and in these commissions common problems are discussed.

Laboratory Facilities

IRSID laboratories now being planned with the assistance of architect R. Coulon are:

1. The Jean Rist building: substation, shops for melting and fabrication, and laboratories for mechanical testing. This building has a floor space of 4627 sq.m. [50,000 sq.ft.].
2. The central laboratory, floor space of 8200 sq.m. [88,000 sq.ft.], with a wing for chemistry and physical chemistry, and another for physics. These two wings are connected by a central block in which are located the administrative, accounting and documentation services.

Available electrical power will be 1000 kva. Personnel of IRSID has now increased to 70 individuals and will soon double. Until such time as the laboratories are functioning, research work is confined to industrial laboratories, advanced engineering schools, and universities. Among these a certain number, known particularly for studies in physical metallurgy, have achieved world fame. Aside from studies made by R. Perrin, G. Chaudron, H. Malcor and G. Ranque, relatively few studies on chemical equilibrium are found in French publications, and this is one branch of study that IRSID will encourage.

The French Metallurgical Society

IRSID does not organize conventions and conferences, as do the Iron and Steel Institute (British) or the *Institute del Hierro y del Acero* (Spanish); this is a job undertaken by the *Société Française de Métallurgie*. Formation of this Society was planned, in March 1940, following a mission to organize Franco-British cooperation

in scientific and metallurgical research. This mission was composed of A. Portevin, head of the mission, and of MM. Chaudron, Chevenard, E. Dupuy, Nicolau, and Rocard. The idea, let drop during the occupation, was taken up again in 1944, immediately after the liberation.

The *Société Française de Métallurgie* forms a connection between scholars and metallurgical engineers, encourages research, organizes conventions and conferences, and publishes papers in the *Revue de Métallurgie*, founded in 1904 by Henry LeChatelier.

The Society is administered by a Council, and directed by a Bureau elected by the Council for one-year terms, except for the general secretary and the treasurer who are elected for three years.

Successive presidents since 1944 have been R. Perrin, A. Portevin, A. Aron, P. Chevenard, P. Nicolau. The general secretary is E. Dupuy.

Connections with the research institutes and technical centers of neighboring industries, already established by close collaboration in research on subjects of mutual interest, are further encouraged by a permanent commission of the Society.

Correspondence

Wrought Iron, Made 70 Years Ago

PITTSBURGH, PA.

A four-masted schooner, the Minnehaha, was built on the Great Lakes in 1880, and wrecked 15 years later. The damaged hull had been half submerged in sand and water ever since the wreck. About a year ago, part of the wreckage broke loose and washed ashore. The wrought iron deck spikes and pins that had held the heavier floor members together were found to be in excellent state of preservation, both inside and outside of the wood.

The writer made some physical tests on a few of the metal pieces. No well-defined yield point was observed for any of the specimens; in tensile strength, all but one conformed to current A.S.T.M. specifications for refined iron bars:

Shape	Dimensions, In.	Tensile Strength	Elongation in 2 In.
Spike	0.42 x 0.42 in.	50,600 psi.	25.0%
Spike	0.52 x 0.51	40,500	17.0
Spike	0.39 x 0.39	53,000	18.5
Pin	0.81 in. dia.	64,900	18.5

Metallurgical and chemical analyses of one of the spikes were made at the metallurgical laboratory of A. M. Byers Co. in Pittsburgh. Analysis of drillings gave 0.012% carbon, 0.020% manganese, 0.274% phosphorus, 0.040% sulphur, 0.190% silicon, and 3.04% of slag. In comparison with modern wrought iron, the phosphorus was high.

CARL W. MUHLENBRUCH
Assoc. Prof. of Civil Engineering
Carnegie Institute of Technology

Immersion Thermocouple in French Steel Plant

UGINE (SAVOIE), FRANCE

The following brief notes on temperature measurement may be of interest in connection with Professor Portevin's article (*Metal Progress* for April 1949) describing the Ugine-Perrin process of steelmaking, as used in our plant.

For more than two years we have been using the quick-immersion platinum/platinum-rhodium thermocouple to measure the temperature of the molten steel in the Ugine-Perrin process. The thermocouple is contained in a steel tube, which is water-cooled down to the terminal elbow. At this point, a thin quartz protection tube is fitted. The terminal elbow is insulated with small annular firebricks.

After the couple has been immersed in the molten steel for 15 to 20 sec., the temperature is recorded on a large lighted dial in full view, and also near the main control panel, where an automatic recorder of high accuracy and quick response registers the time-temperature curves.

The thermocouples are calibrated from time to time by means of a palladium wire having a melting point of exactly 1550° C. (2822° F.). The thermocouple was developed at Ugine, commercially available couples being unsatisfactory for our needs.

R. J. CASTRO
Head of Research Laboratories
Aciéries d'Ugine

Rapid Determination of Susceptibility of Aluminum Alloys to Intercrystalline Corrosion

Washington, D. C.

In order to determine whether specimens of 24S-T3 aluminum alloy are susceptible to intercrystalline corrosion, they are generally immersed in a solution of sodium chloride and hydrogen peroxide as described in Army-Navy Aeronautical Specification AN-QQ-H-186a. This specification requires metallographic examination after immersion periods of 6 hr.

It was found some years ago that the time required could be reduced by an electrolytic procedure to 30 min. or less. The new procedure has been discussed with other investigators, but, so far as the author knows, has not been described in print. Details are as follows:

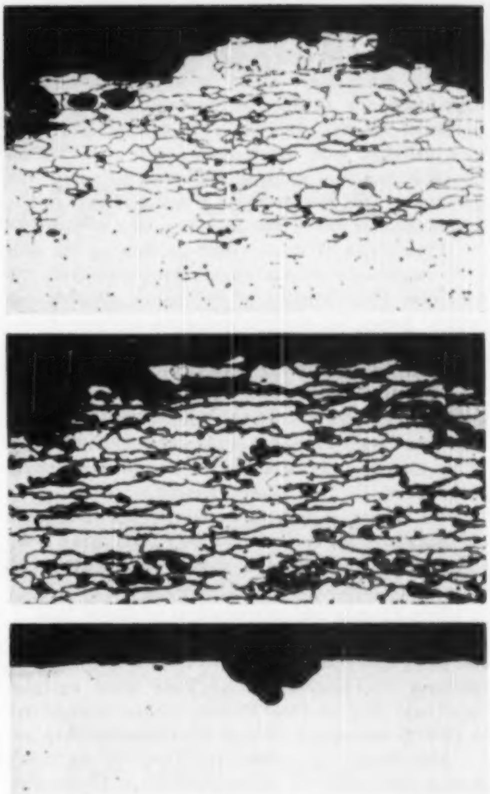
The specimen to be tested is made the anode in a normal NaCl solution. The cathode may be another piece of 24S-T3 sheet of suitable size. The current density is not critical but should be adjusted by rheostat to 0.5 to 2 amperes per sq.in. of surface of the sample tested. After 15 to 30 min. the specimen is removed from the solution and mounted for microscopic examination as described in the specification.

The top micrograph in the accompanying group shows severe intercrystalline corrosion in 24S-T4 alloy, cooled from solution heat treatment in still air and subsequently tested as above for 30 min. The middle micrograph shows severe intercrystalline corrosion in a duplicate specimen given the same heat treatment but subsequently immersed for 24 hr. in the conventional $NaCl + H_2O_2$ solution.

The bottom view shows general corrosive attack and a pit in a third specimen quenched in cold water at 60° F. from the solution heat treatment temperature and subsequently made the anode in the NaCl solution. Corrosive attack (by the electrolytic method) on material immune to intercrystalline corrosion is more general over the surface of the specimen and there is less pitting than was usually found on specimens immersed in the $NaCl + H_2O_2$ solution.

In other experiments the method has been found to check the results obtained by the older, more time-consuming methods on other alloys of the duralumin type and the aluminum-zinc-magnesium-copper alloys.

Hugh L. Logan
Metallurgist
National Bureau of Standards



Corroded Specimens of 24 S-T 4 After Testing. Top is a susceptible sample after 30 min. electrolytic attack, and middle is a duplicate after 24 hr. in $NaCl + H_2O_2$ solution. Bottom is an immune sample after electrolytic attack. All specimens unetched and magnified 100×

Some Experiments on Beryllium Steels

New York City

About eight years ago I was asked to investigate the possibility that quenched beryllium steels might be somewhat stronger than ordinary carbon steels when tempered at the same temperature. (Also that we might find a good nitriding alloy.) The idea behind the work may be stated briefly:

Tempering reduces the hardness of steels and the lowering must be quite substantial (tempered at a high temperature) in order to go beyond the range in which temper brittleness develops. Now, if the quenched steel carried in solid solution something that would precipitate at 500 to 1100° F. without coalescing, this secondary precipitation might

balance the loss of hardness on tempering. Beryllium, which hardens nickel, cobalt and copper enormously, might do the same in steel.

The steels were made in 15-lb. batches in a high-frequency furnace at Rensselaer Polytechnic Institute. Carbon contents were 0.3, 0.6 and 0.9%, each matched with the same amount of beryllium. (Carbon analyses showed the expected amounts; beryllium analyses were not made, but spectrograms showed the proper increases in line density.)

Five series of steels (each containing the nine C-Be combinations mentioned) were prepared, differing in their content of the usual alloying elements. Series No. 1 contained none of these except the minimum amount of manganese and silicon or aluminum needed to obtain solid ingots and insure forgeability; series No. 2 carried 2% manganese; series No. 3 had 2% nickel; series No. 4 had 2% chromium; series No. 5 contained 5% tungsten. (This high content of tungsten was deemed necessary due to its high atomic weight.)

All ingots except those containing maximum amounts of both carbon and beryllium were quite forgeable at 2100° F. and were reduced from 2.5 x2.5 in. to 0.9x0.9-in. bars, which were machined to 0.8-in. rounds and quenched in oil from 1800° F. This temperature was chosen in order to insure complete austenitizing and to obtain large grains for easy micro-examination. Then some samples were tempered at 1100° F. and others brought up to 1800° F. again and allowed to cool in the furnace.

Our hopes concerning resistance to softening during tempering did not materialize.* Alloys with 0.33 and 0.67% added beryllium did not yield hardnesses different from analogous steels containing no beryllium. Those containing more than 0.67% were decidedly inferior (and inclined to rust).

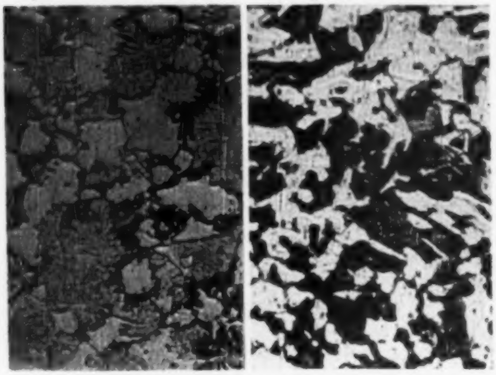
Some interesting microstructures of these steels were photographed by R. Zillman and V. M. Tzvetkov of the metallographic laboratory of Stevens Institute of Technology. Although the micrographs shown in the adjoining column cannot be interpreted fully without some further data (preferably X-ray), they are included here for comparison. None of the alloys could be homogenized by fairly long heating at 1700° F.

While no one, in the present state of metallurgy, is entitled to pass a final judgment on any alloy system, I consider it fairly certain that the possibility of discovering unusually good properties is remote in the iron-beryllium-carbon system.

MICHAEL G. CORSON
Consulting Metallurgist

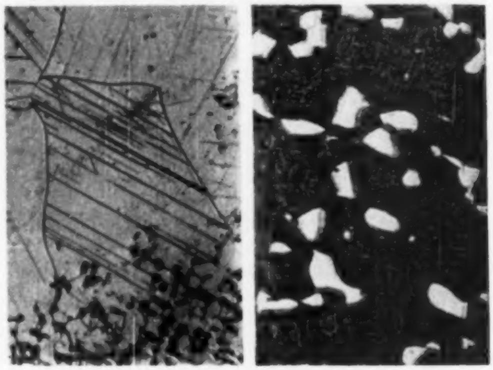
*EDITOR'S NOTE: Recent Austrian work, abstracted on p. 254, indicates that beryllium steels quenched from 1920° F. are more resistant to softening than carbon steels of the same carbon content.

Quenched from 1700° F. — Tempered at 1000° F.



Nominal Composition: 0.3% C, 1% Be

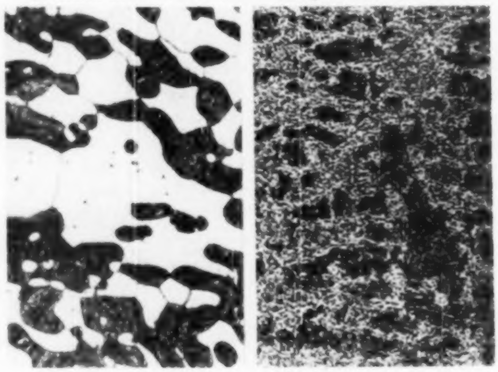
Quenched from 1700° F. — Tempered at 1000° F.



Area near edge of bar, showing heavy segregation — Same sample, area near center of bar

0.3% C, 1% Be, 2% Cr

Quenched from 1700° F. — Tempered at 1000° F.



The dark phase is martensitic — Precipitation has occurred in both phases

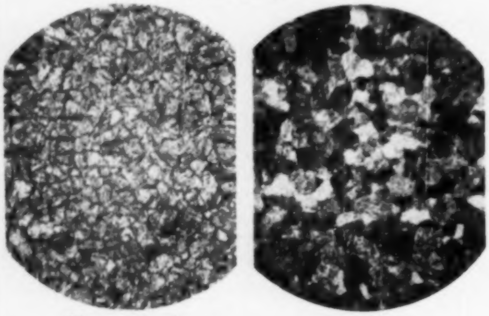
0.3% C, 1% Be, 5% W. All micrographs at 400×

Metallographic Technique for Steel

Action of Miscellaneous Etchants

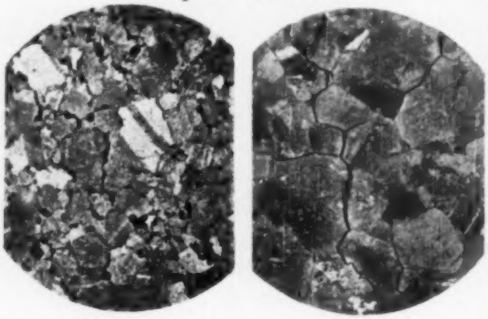
Sheet VI of Six Prepared by Research Laboratory, U. S. Steel Corp.

Martensite



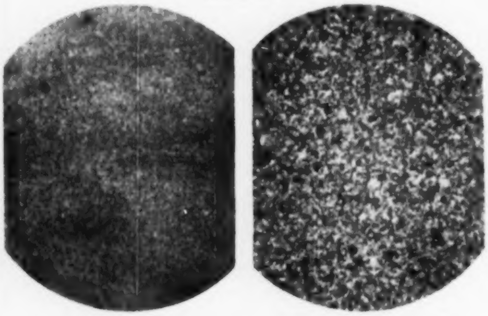
Untempered — Tempered
Etchant: Grain Size Reagent; 100×★

Tempered Martensite



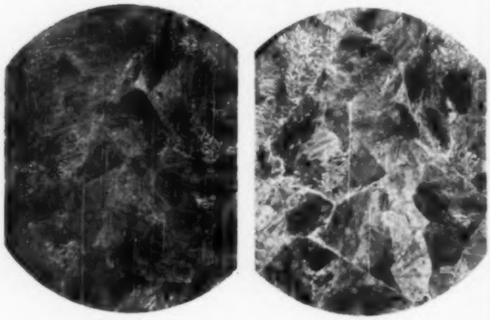
Twins and Fine Pearlite — Path of Fracture
Etchant: Grain Size Reagent; 100×★

Bainite



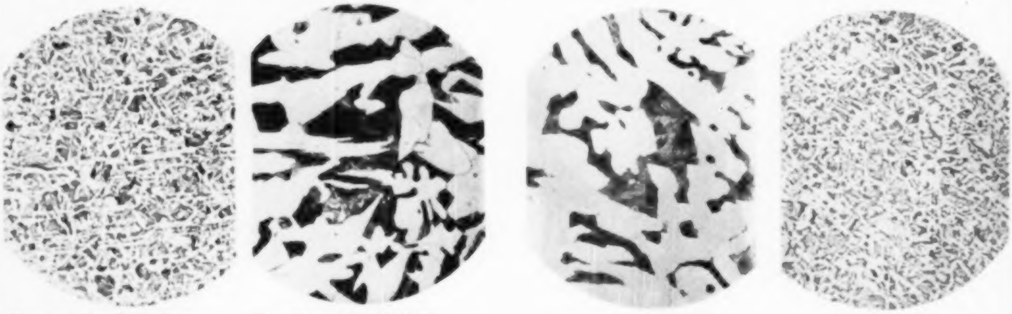
1% Nital — Grain Size Reagent
Etchants as Noted; 100×★

Pearlite Colonies



4% Picral — Modified Grain Size Reagent
Etchants as Noted; 500×★

Depth of Etching Versus Magnification



Correct for Low Power 100×★ — Too Deep for High Power 1000×★ — Correct for High Power 1000×★ — Too Light for Low Power 100×★

★Reproductions herein have been reduced to about one third the original magnifications noted

See also "Metallographic Technique for Steel", by J. R. Vilella, published by The American Society for Metals

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BAUSCH & LOMB *Metallographic* EQUIPMENT

Brazing and Welding Methods for Subassemblies

Report of an
Economy-in-Production
Round Table Discussion

By P. H. Brotzman
Lawrence Jacobsmeyer
J. N. Woolrich
and S. M. Spice

ONE OF THE FEATURES of the technical sessions at the last annual convention of the ⊕ was a series of round table discussions on various metallurgical operations. The underlying theme of all was "Economy-in-Production". A group of experts discussed various aspects of a general problem; participation by members of the audience was invited (and was frequently vigorous). Verbatim records of such meetings would take more pages than *Metal Progress* can afford; nevertheless the high lights of one on the Economics of Brazing and Welding Methods for Subassemblies are presented here. CHARLES E. MACQUIGG, Dean of the College of Engineering of Ohio State University, acted as Chairman.

Silver Brazing

P. H. BROTZMAN* — In any consideration of the relative merits of the various joining methods we now have under discussion there are really only two fundamentals: First, the engineering requirements of the part to be manufactured; second, the economics of the operation — often dependent on the quantity to be produced. In such an analysis one appealing aspect of silver brazing (as compared to copper brazing, for example) is its versatility. Copper brazing requires a furnace and an atmosphere generator — a rather expensive installation — and there are many places where the volume of the work does not justify it. There is also the problem of joining brass or other copper-base alloys where copper brazing cannot be used. As a case in point, we had a valve job where we wanted to join a piece of Armco ingot iron to a brass tube and it, in turn, to a screw machine part of austenitic stainless steel. It was rather a weird combination, but silver brazing provided an answer.

Ideally, the method of joining should improve the essential properties of the materials used — at least not lower them. Consequently the operating temperature is often important because of its effect on grain size and physical properties.

Silver brazing (or silver soldering) utilizes a group of silver alloys that melt and flow within the range of 1200° to 1500° or 1600° F. Heating steel, brass or other strong alloy to that temperature is going to have the effect of annealing it — or at least a low-temperature normalize, depending on the rate of cooling. If it were previously hardened it may be softened at that point where it is heated for brazing. If it is furnace brazed, of course it is softened all over.

The method of heating for silver brazing often depends on the quantity involved. A great deal of torch brazing is being done; it is a very handy and satisfactory method. Induction heating is also very popular; sometimes furnace brazing is indicated; we also have salt bath heating and resistance brazing — that is to say, heating by passing electrical current across the joint. Now the *method* you use is one that you as an individual, considering your own engineering problem, have to decide.

*Chief Metallurgist, Parker Appliance Co., Cleveland.

Probably every one of these methods has its advantages and some inherent disadvantages. I will cite a few examples:

Electrical heating elements are silver brazed (rather than soft soldered) into coffee makers to avoid failure from accidental overheating and for better electrical conductivity.

Gears for farm machinery were hobbed by multiple gang work from blanks of 1045 steel plate, and a small sprocket brazed on with induction heat. The localized heat did not soften the hardened teeth. When you just want to braze one small part into a very large stamping, it is uneconomical to heat the entire mass. Whether or not you use induction or torch has to be decided usually by the design of the part. Obviously it can be difficult to get an induction coil around many places and to design a fixture to position the parts; in those cases a torch should be considered. However, when properly tooled-up, the heating cycle in most induction-heated joints is less than a minute, and you get production rates of 70 or 80 an hour with one person operating the equipment, and more if multiple coils are used.

The type of fit between the component parts is important. For silver brazing we prefer to have loose fit; a clearance of 0.001 to 0.005 in. on the diameter, for instance, is a general rule that we follow at our plant, 0.002 to 0.003 being ideal.

The importance of having the component parts properly cleaned and fluxed is generally well understood. It is sufficient to remind you that the parts should be chemically clean, and protected during heating by suitable flux if consistently well-filled joints are to be secured. We maintain a minimum standard of an 80% fill as determined by X-rays, used as spot check on quality.

Brazing wire in the form of rings often speeds assembly; in other cases shim stock or powdered solder mixed with flux is more convenient than wire. In fact, the great versatility and possible variations in the silver brazing process help explain its great popularity in contributing to "Economy in Production".

Copper Brazing

Lawrence Jacobsmeyer* — Our company, being in the commercial brazing business, uses furnaces designed specifically for copper brazing, although these furnaces may also be used for silver soldering and bright normalizing. Most brazing furnaces are heated electrically with auxiliary equipment supplying the necessary reducing atmosphere.

Figure 1 shows the discharge end of a 20-in. mesh belt, electric brazing furnace; a water jacketed cooling chamber occupies most of the view. At the left is the atmosphere converter which burns gas in limited air at about 2000° F. The atmosphere is then run over a catalyst brick and through a water jacketed condenser which removes some of the moisture. The resulting atmosphere contains about 18% hydrogen, 72% nitrogen, and the remaining 10% is a mixture of CO, CO_2 and methane. Because of the long cooling chamber, also under atmosphere, the work comes out with a silvery white finish.

Of course, copper brazing depends for its success upon the ability of molten copper to "wet" steel — and that, in turn, induces capillarity. Generally, flux is not needed because the reducing atmosphere cleans the steel surfaces of oxides which prevent wetting. (Flux is used in silver soldering to dissolve, or break up, the ever-present oxide film.) In order to induce wetting and subsequent capillarity, metal-to-metal contact must be maintained at temperature. This means that press fits are desired in copper brazing — just the opposite of what Mr. Brotzman says is required in silver brazing.

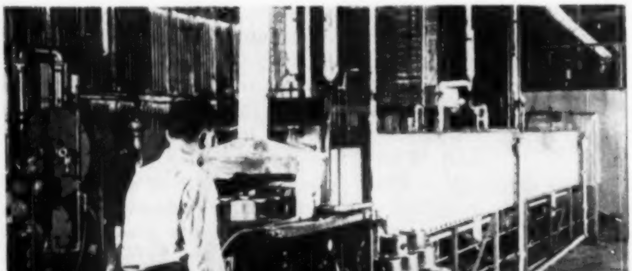


Fig. 1 — Discharge End of Brazing Furnace With Long Cooling Chamber. Proper atmosphere delivers steel parts with silvery-white surface

*General Manager, Salkover Metal Processing of Illinois, Chicago.

The best illustration I have of the effect of capillarity in a steel assembly is the old M-69 incendiary bomb. (See Fig. 2.) It has a thin cupped stamping *A*, a thick cupped stamping *B*, a $\frac{3}{16}$-in. flat stamped washer or "impact diaphragm" *C*, and a little slug *D*. The flat stamping, together with the slug, is placed within the heavy stamping, the thin stamping *A* pressed over this assembly, and then this assembly pressed into the hex tube *E*. The end shown is depressed about 2 in. below the other and a slug of copper is dropped in this opening and comes to rest at point *F*. Thus, when the

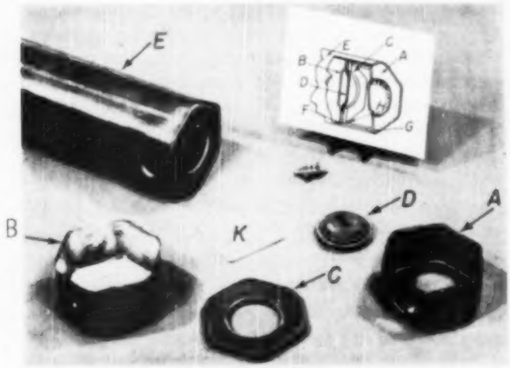


Fig. 2 — Parts of M-69 Incendiary Bomb, and Sketch of Brazed Assembly

copper melts, it is drawn through the joint by capillary attraction between the outer hex casing and the adjacent drawn thin stamping. When the copper reaches the end of the assembly at *G*, it forms a fillet bridging the gap between the heavy nose cup and the casing. Having bridged this gap with a fillet, the copper then creeps back almost the same distance in the opposite direction to *H* where the nose cup butts against the impact diaphragm *C*. This copper creeps up and around the joint by capillary attraction, leaving a fillet in the corner along all six sides of the impact diaphragm, and in the meantime has penetrated all the way up through the joint outside and inside the sealing diaphragm, making a uniform, tight seal completely around the casing. A piece of asbestos paper *K* prevents the impact diaphragm and sealing diaphragm from brazing together.

For good results in copper brazing, three things are necessary — cleanliness, surface smoothness and press fits.

For best results, parts should be cleaned in a vapor degreaser, or by some other suitable method. If an alkali cleaner is used, the parts should be rinsed thoroughly and then left to dry before assembling. No lubricant, such as oil or white lead, should be used when pressing the parts together. Surface finishes of 40 to 100 micro-inches (root mean square) give best results. A press fit on such an assembly will wipe the high spots off of each component, still allowing a press fit. If two or more smoothly ground surfaces are pressed together, the surfaces will gall and copper cannot properly penetrate.

Press fits of approximately 0.001 in. per in. of diameter is a good rule-of-thumb. The copper alloys with the steel on either side, metallic grains grow across the joint, and the shear strength approaches 33,000 psi. Shear strength decreases progressively as the fit becomes open until it reaches 0.003 in. loose fit, whereupon the strength of the joint is no more than the shear strength of the copper — namely, about 20,000 psi.

There are various ways of holding peculiar shaped stampings together, such as riveting, spinning, staking and spot welding. Fixtures should be employed only as a last resort because they absorb valuable heat. They also warp and stretch under repeated high temperatures.

I could show photographs of hundreds of successful applications. Many business machine parts and adding machine parts are copper brazed. These parts were formerly staked, riveted, or had the edges spun over. One particular part would work loose after 200,000 blows on a certain test. Brazed parts have run up to 5,000,000 without showing signs of failure with the same test equipment. Tensile strengths increased from 50% to nearly 300%, depending on the part. Manufacturing savings varied from $10 to $150 per thousand. The cost of service calls for repair of broken parts has been cut enormously.

More frequently-met applications are substitutions of several simpler subunits, machined or stamped, for a large part, difficult or wasteful to machine, even when made of relatively cheap stock like cast iron. Other parts can be redesigned to put strength into regions where service failures occur. The number of joints that can be brazed in one pass through the copper brazing cycle is only limited by the ingenuity of the designer. We ran one radiator in which we copper brazed 651 joints in one pass through the brazing furnace!

[At this point a member of the audience cited an interesting assembly of a gas engine valve lifter which was to be hardened on the wearing face. The two components were made on automatic machines, the body being hollow, and the end threaded where the foot or plug screw goes in. The plug had a small groove turned in it and a 70-30 brass ring snapped into it and fluxed with

borax. Then the parts were carburized at about 1725° F. At the end of the 7-hr. carburizing operation the braze was completed and the plug quench hardened. This was an example of brazing which took place in a conventional operation.]

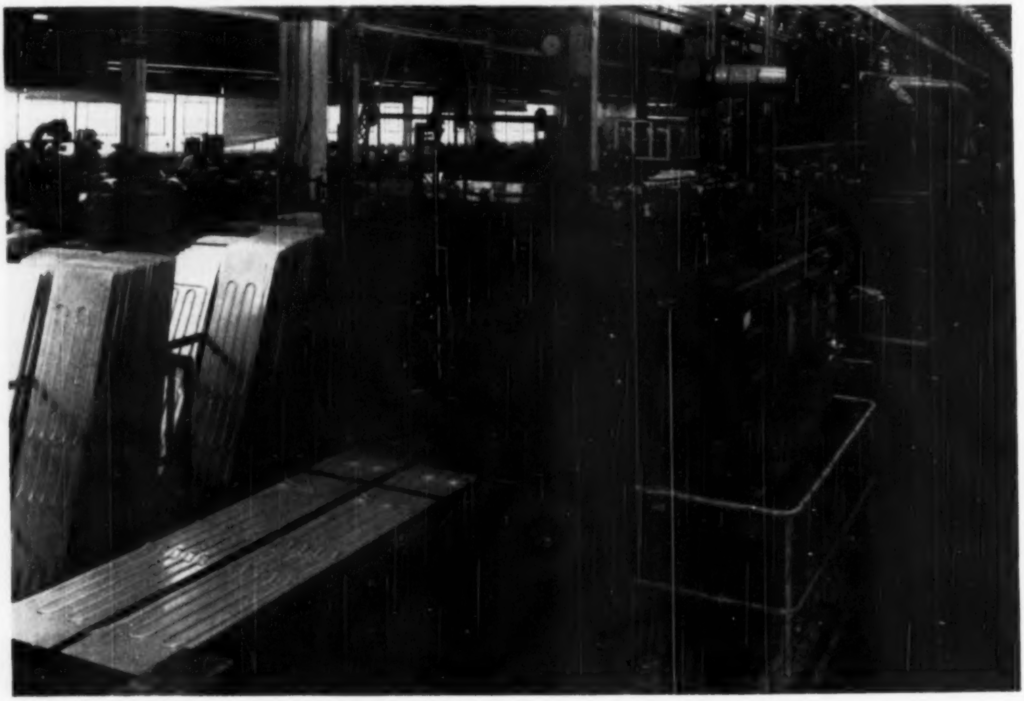
It is sometimes economical to plate one of the component parts of small steel assemblies to provide copper brazing metal for the joint. A small piece can be barrel plated to a dimension of 0.0002 or 0.0003 in. and then assembled. Besides copper wire in the form of rings or hairpins, copper shim or copper oxide can be used to supply brazing material to the joints. Copper oxide can be mixed in various mediums, such as lacquer; "No. 4 steel-cut copper powder" can also be used with the same medium. The idea is to get the brazing metal as close to the joint as possible, using the most economical method. The so-called "liquor finish", wherein the parts are dipped in sulphate solution and the copper plates out in just a film, will seldom provide sufficient copper. If it is necessary to remove any copper flash, or excess copper, from the steel assemblies, this can be done by reverse plating, or by using a solution such as "Kelite".

One additional thought occurs to me, and that is, it is possible to heat treat steel assemblies after copper brazing without affecting the copper brazed joint.

Brazing of Stainless

We have been quite successful, continued Mr. Jacobsmeyer, in joining stainless steel tubes which were copper plated inside and outside, the smaller tube inserted into the larger tube, and the smaller tube expanded for a tight fit. The ensuing copper brazing cycle is done in a regular commercial atmosphere. Copper plating protects the parts so chromium oxide does not form before they reach brazing temperature. We have also been able to braze stainless with copper rings, using a slight amount of flux to prevent formation of chromium oxide. Another method is to put the stainless assembly in a bell-type furnace with a *dry* hydrogen atmosphere (dew point of −60° to −70° F.).

Fig. 3 — Continuous Furnace With Mesh Belt, Accurately Controlled as to Temperature and Through-Time for Brazing Aluminum Tube to Sheet. Flat parts shown will later be bent into U shape; looped tubes will then hug the rounded corners



No flux is needed in this operation and the stainless comes out brighter than when it went in. This is rather expensive because of the atmosphere, which might be made of cracked ammonia or bottled hydrogen. Stainless must be deoxidized or deactivated before copper plating will "stick"; a 0.0001 or 0.0002-in. copper plate is sufficient.

Copper brazing is done in a temperature region where the austenitic solid solution of 18-8 stainless is unstable and certain undesirable changes in properties may be expected. Much of this danger is avoided if the parts are cooled quickly. Fortunately, our work has been done on thin sections and they cool rather rapidly in the water jacketed extension of the brazing furnace, and our customers have not been bothered by carbide precipitation.

Aluminum Brazing

J. N. Woolrich* — While the brazing of machined and forged parts of aluminum alloys into complicated units is a successful operation, and sheet has been brazed into gasoline tanks for 100 psi. pressure, I will confine my remarks to the work with which I am intimately familiar:

In the manufacture of refrigerator shelves, liners and evaporators, especially for home freezers, the problem was to attach long continuous lengths of lightweight tubing (for carrying the liquid refrigerant) to relatively light-gage sheet (which forms the freezer wall or shelf). Our first thought was to use copper sheet and copper tubing for its efficient heat transfer, but that presented a problem in the economics of soft soldering, and then finding some means of protecting them from the corrosive conditions such as what you might expect in the refrigerator — I mean, from fruit juices, all kinds of food, milk and butter. We also considered copper tubing on a galvanized steel sheet; the basic material was cheaper but the protection problem then became major. Finally we arrived at continuous furnace brazing of aluminum; it proved to give us the necessary requirements of good heat conductivity, high possibilities in mass production, and the metal could be anodized for ample corrosion resistance.

When I say we braze long continuous lengths I mean flat or dimpled aluminum sheets 0.040 in. thick, from 12 to 20 in. wide up to 120 in. long, with 30 to 55 ft. of tubing brazed to that sheet — brazed well enough to give very good heat transfer. Figure 3 shows how such an assembly enters a brazing furnace.

*Metallurgist, Works Laboratory, Refrigerator Division, General Electric Co., Erie, Pa.

Two methods of assembly have been used. In one, the flat sheet is coated on one side with brazing alloy and the tube is held by small pieces of bent strip, spot welded to the sheet. Such clips may be made of 2S or 3S and remain as part of the assembly, or can be made of brazing alloy, which melts during the operation. The other scheme uses a thin channel section of brazing alloy to hold the tube during its passage through the heating zone.

The metal of the sheet and tube is used as it reaches us from the mill — that is, no preliminary cleaning is necessary. Alloy in this particular job is aluminum of commercial purity (2S) or 3S (1½% manganese). The joint is made with 5 or 7½% silicon-aluminum, generally known as "7-13 brazing alloy", applied separately as a filler strip, or on the sheet similar to a clad material. The differentials between melting point of parent metal and brazing material is very small, within a range of approximately 50° F. That means a very accurate temperature control within the furnace.

In conventional continuous furnaces such as used for copper brazing, the on-and-off contactors gave temperature swings much too wide for a

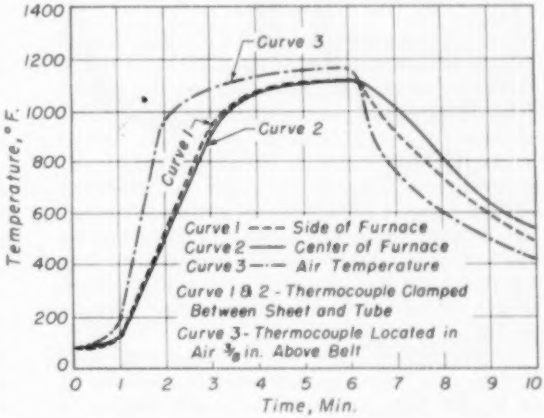


Fig. 4 — Temperature Survey of Aluminum Brazing Furnace. Especial accuracy is necessary

good job on aluminum. Our furnace has a 24-ft. heating zone and a 10-ft. cooling zone. The heating zone is divided in three sections, the first is on contact control, the second and third sections are on G.E. "Reactorol" control. A typical operation would be running at a belt speed of 58 in. per min., so the total time through the furnace is around 10 min. (Fig. 4).

The brazing temperature of this particular

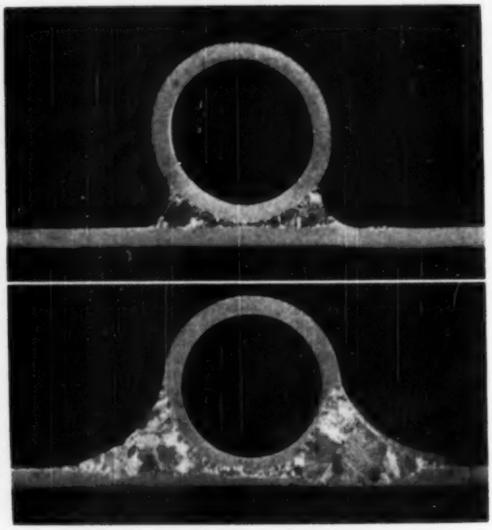


Fig. 5 — Top Is a Brazed Section Where Temperature and Time Have Been Adjusted Correctly. Bottom is an example where "wash" has penetrated more than half of the tube wall at 4 o'clock

alloy is between 1130 and 1140° F., and the time at brazing temperature is approximately 1 or 1½ min. With this small differential, between the melting point of the parent metal and the brazing material, we have a Wheelco "Limitrol" on all these sections in case anything should go wrong with the furnace control. You can readily imagine that otherwise we might have a furnace full of melted aluminum!

Naturally in a continuous mesh belt furnace and particularly where the belt load is more than the part load, the location of the control points should preferably be as close to the work as possible.

Chain speed is also very critical. Differences of 3 to 4 in. per min. with normal operation of 58 in. per min. can cause unbrazed sections if travel is too fast, or washed-through sections if parts are held too long at brazing temperature.

It is therefore quite necessary for thermocouples to be as close to the work as possible. The original program is set up by placing a thermocouple with long leads *between* the tube and the sheets and running it through the furnace to get the temperature characteristics (see Curves 1 and 2 of Fig. 4).

Since we are working in a narrow temperature range with thin-walled pipe, "wash" action must be prevented. In other words, the molten braze must not carry too much of the pipe wall down into the casting that forms the actual joint. An example is in Fig. 5, bottom. If the temperature and time are correct a very small fillet is formed, the original thickness of sheet and tubing are maintained, and there is very little wash action (Fig. 5, top). While we are not putting these together for mechanical purposes, yet the tube carries the refrigerants and must be gas tight; consequently we beware of weakening the wall.

In aluminum brazing the clearances are not as exacting as with copper brazing. While intimate contact is desirable, we have obtained a very satisfactory braze with $\frac{1}{16}$-in. clearance.

Another thought is that the flux is a chloride-fluoride mixture and it is quite corrosive on furnace parts. Heating elements and the belt of these furnaces are made of 80-20 nickel-chromium, and they have fairly satisfactory life, although considerably shorter than heat treating furnaces operating at comparable temperatures.

The cooling chamber is approximately 10 ft. in length; it just cools the sheet down fast enough so that it can be handled very quickly. It is very advantageous to quench the warm parts almost immediately; then you form steam which does a great deal in knocking off the flux. Next is a cold deoxidizing rinse, next a hot water rinse.

The part is then immersed for 2 to 3 min. in a solution of 1 to 3 oz. of alkali cleaner at 160° F., followed by a water rinse. It is then given a 15% nitric acid dip followed by a cold and hot water rinse (160° F.) and blown dry with air. This finishes the cleaning operation after brazing.

After forming and assembling, the liner or evaporator is cleaned to give a uniform bright surface, free of scratches or stains. It is then anodized (sulphuric) for corrosion resistance.

Welding

S. M. Spice* — In a large automotive plant such as ours, we use all of the methods of brazing and soldering that have been mentioned this afternoon except aluminum brazing — primarily because aluminum is used very little in automotive parts. Our reasons for selection of joining method are dictated by the size of the part, the strength required, the operating cost, and the capital to be invested in equipment.

From a considerable number of items of current practice I will select two. The first is automatic inert-arc welding of fender blanks.

In the styling of automobiles, some of the draws in sheet metal have become so deep that there is increasing trouble from splitting the mate-

*Welding Engineer, Metallurgical Dept., Buick Motor Division, General Motors Corp., Flint, Mich.

rial. Front and rear fenders have come to that point. Some means had to be found to help that situation. At first we heated the nose of the one-piece fender. In the present method the blank is notched slightly at the forward end and folded so it looks like a pup tent with one end closed. Where the two edges come together the joint is welded.

We started out with hand welding, but it was slow and we experienced some difficulty due to the human element. With an automatic, inert-arc welding head and a wire feed to add the filler metal, we are able to get something like 60 fenders per hr., and the output is much more uniform. This welded piece then forms the blank for press shop operations.

There does not seem to be any difference in the way the weld metal flows in the die as compared with the other parts of the metal sheet. We try to keep the weld bead as flat as possible. If a weld is made without added filler there is a slight sink at the joint at which the drawing stresses concentrate. With a little added metal the part goes through the forming dies all right, and there is not much finishing to be done afterward.

Filler metal also has to be added for rimming steel (and sometimes with killed steel) to avoid porosity in the weld. We use a low-alloy filler rod; we have tried many alloys; they all seem to work; in fact I am not at all sure that an alloy is necessary, but it has to be made of killed steel.

The other part I want to discuss has evolved through several interesting stages. It is a small brake band for the "dynaflow" transmission. Figure 6 shows the original construction, as well as the present, more economical design.

In the interests of safety we started off with a one-piece construction — rolling up a very heavy band. This was done hot. Ten of them were put side by side in a fixture and welded by submerged arc into complete circles. (We started out by hand welding; one man was able to weld 20 of those bands in 8 hr. By submerged arc it took not over 75 sec. to weld 10 bands.) Then we had to hog out all of the material down to the finished dimensions, bore the band, line it, and split it apart. We started out with 6 lb. of material and ended up with $1\frac{1}{2}$ lb.

Despite the fact that our designers were suspicious of welded attachments where loads are high, we finally convinced them that these bands could be made in a more economical manner. We now start off with a band which is of the finished thickness, roll it up cold, form projections on each end of the band, and spot weld a bar across the end which closes the ring. Then we braze the joint between band and bar and have the advantage of two methods of attachment — spot weld and braze. (The projection welds are purely to hold the part together during brazing, so we don't consider that they contribute a very large share of the total strength of the piece.)

We now have a thin band — the finished thickness actually — held in a complete circle by a bar across the top. The band requires only a broaching operation to bring it to its finished shape. We get rid of the boring operation by expanding the brazed band to its finished size, and are able to hold to 0.004 in. total tolerance better than we did in our former machining operations because the band is rather flimsy. It only remains to affix the lining by a plastic cement, then slit it apart, and the band is done. So in this later method we start off with steel parts weighing 1 lb. 12 oz., and finish up a little under $1\frac{1}{2}$ lb. — a $4\frac{1}{4}$-lb. saving in material. Cost has also been reduced to one third that for the previous method.

Fig. 6 — Brake Band for Dynaflow Transmission. A-1 to A-3 at left show original construction from thick ring; B-1 to B-3 at right show economical construction with spot welded and brazed assembly

Movements Among Metallurgists

Alvin J. Herzig has recently been elected president of the Climax Molybdenum Co. of Michigan, the research subsidiary of Climax Molybdenum Co. Mr. Herzig joined Climax in 1931 as chief metallurgist.

Henry B. Allen, executive vice-president and secretary of the Franklin Institute of the State of Pennsylvania, has been awarded an honorary degree of Doctor of Engineering by Drexel Institute of Technology, Philadelphia.

The Aluminum Co. of America announces the appointment of **Maurice W. Daugherty**, formerly chief of the Cleveland Research Division, as secretary of the Aluminum Research Laboratories, New Kensington, Pa. **Walter E. Sicha**, formerly an assistant chief, will be appointed chief of the Cleveland division to succeed Mr. Daugherty, and **Allan M. Montgomery**, who has been head of the metallographic group since 1940, will be promoted to assistant chief.

Francis B. Foley

Past-President **Francis B. Foley** has resigned his 34-year connection with Midvale Co. to become metallurgical consultant for International Nickel Co.'s research laboratory at Bayonne, N. J. Foley's work at Midvale really started in 1906 in the melt shop, but since 1909 (except for a nine-year interlude) he has been in the research department — its head since 1926. He has thus participated in the expansion of applied metallurgical science practically since its beginning in the United States. During and after World War I he worked with Henry Marion Howe in the completion of the final works of the master.

Adolph Bregman

Harold J. Roast

The Editor and Business Manager of *Metal Progress* take much pleasure in introducing to the readers two consulting editors, **Adolph Bregman** and **Harold J. Roast**, specialists respectively in the fields of cleaning, plating and finishing, and of the nonferrous metallurgical industry. Their assignment is to report newsworthy events, and — at regular intervals — to consider important aspects of their fields in general terms. Such articles by each appeared in the January issue.

Mr. Bregman is a graduate of the Colorado School of Mines. After several brief engagements in the smelting and refining industry (and with Uncle Sam's army), he became Managing Editor of *The Metal Industry* in 1919, holding that position for 21 years. Since that time he has been a consulting engineer and executive secretary of Masters' Electro-Plating Assoc.

Mr. Roast was educated in England, a graduate of City of London College. He emigrated to Canada in 1902 and for 12 years was in the refractories industry. Since 1914 he has been in nonferrous foundries, becoming metallurgical director of Robert Mitchell Co., Ltd., in 1928, and technical advisor to Canadian Bronze Co., Ltd., in 1933 (later vice-president and consultant). He has been special lecturer in metallurgy at McGill University since 1918.

Robert F. Mehl, director of the metals research laboratory and head of the metallurgical engineering department of Carnegie Institute of Technology, has been appointed a member at large of the National Research Council of the National Academy of Sciences.

Latrobe Electric Steel Co. announces the appointment of **Robert F. Frazure** as district manager of the Southwest district, with headquarters in St. Louis, Mo. Mr. Frazure has represented Latrobe in the Toledo and Chicago districts previously.

Clinton E. Swift has joined the American Brass Co., Waterbury, Conn., as welding specialist. He was also with American Brass from 1931 to 1939.

Massachusetts Institute of Technology announces the appointment of **Frederick H. Buttner** as an instructor in the department of metallurgy. Mr. Buttner has been a member of the M.I.T. research staff since 1947 and is a graduate of Michigan State College and M.I.T.

Makers of the NEW UNIVERSAL COFFEEMATIC

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YEARLY SAVING of over $10,000.

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To pickle and anneal the body of their new coffee pot was costing Landers, Frary & Clark, makers of the famous line of Universal appliances, $7.50 per M pieces. 5 anneals, which at first seemed necessary to produce the quality product for which Universal is nationally known, jumped the cost per M pieces to $37.50. Universal knew this was far too high and decided to do something about it.

Their metallurgist, in cooperation with Revere, studied the problem in detail and then proved their conclusions by exhaustive tests. It was found that by using Revere copper strip in a certain temper, 4 anneals could be eliminated. Now, after a draw of 7¾", the copper body is annealed once then spun into its finished shape. Based on current production, this has resulted in a saving of over $10,000.00 per year, plus an improved product. Additional savings also are realized through more simplified handling, and more economical finishing operations due to the reduction in the number of anneals.

To make such a deep draw while holding rejects to the absolute minimum would not be possible were it not for the fine quality and consistent uniformity of the gauge and temper of the copper used. The copper body is tin plated inside, while the outside is first nickel plated then chromium plated.

Because of the nature of this appliance, which makes coffee automatically to the individual's taste, then reduces the current to keep coffee at serving temperature, Revere copper was selected for its high thermal-conductivity. This makes it possible to brew the coffee faster and keep it hot longer, thus saving on current.

Perhaps Revere Copper or some other Revere Metal can be of help in developing or improving your product—cutting your production costs. Why not tell Revere about *your* metal problems? Call the Revere Sales Office nearest you today.

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Personals

Republic Steel Corp. announces that **Louis Geerts** has been appointed eastern sales representative. Mr. Geerts has been with Republic in sales capacities since 1930 and previously represented the Union Drawn Steel Co.

Cooper Alloy Foundry Co. announces the appointment of **Herbert J. Cooper** as assistant to the general manager. He was formerly engaged in research at the foundry.

R. R. LaPelle, formerly vice-president of the Dempsey Industrial Furnace Corp., has joined Westinghouse Electric Corp., Springfield, Mass., as an industrial heating specialist.

J. E. Simonin, who has been with the Pittsburgh Steel Co.'s Allenport, Pa., plant for 20 years (most recently as plant metallurgist), is now works manager of the plant.

Robert E. Shoup has been appointed general superintendent of the Colonial Steel Division, Monaca, Pa., of Vanadium-Alloys Steel Co.

American Brake Shoe Co. announces that **Paul L. McCulloch, Jr.,** has been transferred from Rochester, N. Y., to Pittsburgh, Pa., where he will serve as sales engineer for the American Manganese Steel and Electro-Alloys Div.

B. B. Button has been promoted to the position of special assistant to the general sales manager of the Diversey Corp., Chicago.

Thomas C. Ford, formerly district sales manager of Electro Metallurgical Co. in the Pittsburgh area, has become associated with Pittsburgh Metallurgical Co., as sales agent in the Pittsburgh territory.

The Dexter Co., Fairfield, Iowa, announces that **Joseph Farley** has joined its organization as sales representative for the Dexter gray iron foundry.

Stoody Co., Whittier, Calif., announces that **Charles E. Rogers** has been advanced to the position of sales metallurgist. He has been in charge of the metallurgical laboratory for the past three years.

Raymond J. Shillum has been elected a member of the board of directors and appointed vice-president in charge of sales of Brown-Hutchinson Iron Works, Detroit. Mr. Shillum was formerly sales manager directing alloy sales.

Reynolds Metals Co., Louisville, Ky., announces that **Stuart Smith** has been appointed product manager of sheet and plate sales. Mr. Smith was most recently manager of aircraft sales for Reynolds Metals.

D. Gardner Foulke has been appointed chief chemist in charge of analysis and customer service for Hanson - Van Winkle - Munning Co., Matawan, N. J. He has been process electrochemist of the company for the past three years.

John Molloy, who has been with Armco International Corp. since 1923 as technical advisor, chief metallurgist, technical director and most recently as director of the technical division, has been recently elected a vice-president.

Vincent M. Drost, formerly lubrication engineer at Continental Motors Corp., is now president of Milclean Products, Inc., Muskegon, Mich., a newly established company manufacturing grinding compounds and emulsion cleaners.

American Tank & Fabricating Co., Cleveland, announces the election of **K. J. Humberstone**, chief metallurgist, as a director of the company.

Personals

International Nickel Co. announces that **G. R. Brophy** will head the New England technical section of International Nickel's development and research division in Hartford, Conn. Mr. Brophy was previously at the Bayonne, N. J., laboratory of the company where he was in charge of the steel section.

Richard W. Wilson has joined the staff of Armour Research Foundation as assistant metallurgist.

Having obtained his master's degree in metallurgical engineering at the Missouri School of Mines and Metallurgy, **Walston Chubb, Jr.**, is now an engineering trainee at the Brush Beryllium Co., Luckey, Ohio.

Maurice F. Baldy is now employed in the metallurgical department of the Weirton Steel Co., Weirton, W. Va.

Donald G. Giacomo, formerly a student at the University of Utah, is now in the industrial engineering department at Geneva Steel Co., Geneva, Utah.

Holcroft & Co. announce the appointment of **Wallace F. Schott** as representative for Ohio and western Pennsylvania. Mr. Schott was formerly sales manager of Lee Wilson Construction Co. and has also recently organized Wallace F. Schott Co., Cleveland.

Following receipt of his B.S. in metallurgy from Columbia University, **George R. Prescott** joined the technical section of E. I. du Pont de Nemours & Co., Belle, W. Va., as metallurgist.

John L. Petz, formerly chief engineer of International Business Machines Corp., Typewriter Div., is now engaged in industrial engineering consultation in Poughkeepsie, N. Y., specializing in machine design and tool design service.

Gregory J. Azarian has been transferred by American Brake Shoe Co. to its engineered castings division in Rochester where he will be a sales representative. He was formerly an assistant metallurgist in the metallurgical department.

Maurice C. Fetzer, formerly with Latrobe Electric Steel Co., is now in the research and development laboratory of the Kaiser Aluminum & Chemical Corp., Spokane, Wash.

After receiving his M.S. from Massachusetts Institute of Technology in September 1949, **Henry Paige** joined Sylvania Electric Products, Inc., electronic division, Boston, Mass., as production liaison engineer on metal and material problems.

Arthur E. Beyersdorf, formerly at Globe Steel Tubes Co., is now with Cleaver-Brooks Co., Milwaukee.

Gordon C. Pfaff, a recent graduate in metallurgical engineering of the University of Minnesota, is now in the materials engineering laboratory of Deere & Co., Moline, Ill.

Paul Wamsley, Jr., who graduated in June from the University of Cincinnati, is now employed at the Baton Rouge, La., refinery of the Esso Standard Oil Co. as an engineer for equipment inspection.

Edward C. Zuppann, formerly with Wilson Foundry & Machine Co., is now chief metallurgist at plant 1, Oliver Corp., South Bend, Ind.

Claud S. Gordon Co., Chicago, announces the appointment of **Benj. S. Sampson** to manage its Industrial Furnace & Oven Div. Mr. Sampson was formerly district manager for the Stewart Furnace Div. of the Sunbeam Corp.

Personals

Having received his B.S. degree from the University of Illinois in August 1949, **Robert C. Bertossa** ⊕ has joined the Chicago Bridge & Iron Co., Chicago.

Richard C. Barry ⊕, formerly with the Pearl Harbor Naval Shipyard, has been transferred to the San Francisco Naval Shipyard in the radiological defense laboratory where he is materials engineer and metallurgical consultant.

Ralph W. Preston, Jr., ⊕ is now a metallurgist trainee at the Timken Roller Bearing Co., Canton, Ohio.

Jack J. Bodzin ⊕ has joined the Detroit Fisher Body Div. of General Motors Corp. as a laboratory technician at central engineering activities.

Eldon H. Lockhart ⊕ has left his former position as shop superintendent at the microwave laboratory, Stanford University, and has accepted a position as research laboratory analyst with the antenna and microwave section of the Hughes Aircraft Co., Culver City, Calif.

Sidney Brotman ⊕ has recently assumed charge of the precision casting division of Alfred Hofmann & Co., West New York, N. J.

Ernest D. Fahlberg ⊕, formerly director of research, Grede Foundries, Inc., Milwaukee, is now doing special steel melting research in the school of mineral sciences, Stanford University, Stanford, Calif.

William J. Levy ⊕, formerly with Ampco Twist Drill Co., is now co-owner of the Industrial Steel Treating Co., Jackson, Mich.

Robert E. Lenhart ⊕ has joined the chemical and metallurgical training program of the technical education division, General Electric Co., Schenectady, N. Y.

After completing three years of graduate work at Carnegie Institute of Technology, **Donald E. Thomas** ⊕ is now in the materials and metallurgy section of the atomic power division of the Westinghouse Electric Corp., Bettis Field, Pittsburgh.

T. H. Gray ⊕, formerly with Metallurgical Engineers, Inc., is now employed as research engineer at Boeing Aircraft Co., Seattle, Wash.

Charles M. Monday ⊕ has been transferred by B. F. Coombs Co. from sales engineer in the Lake Charles, La., area to manager of engineering sales at the main offices in Houston, Tex.

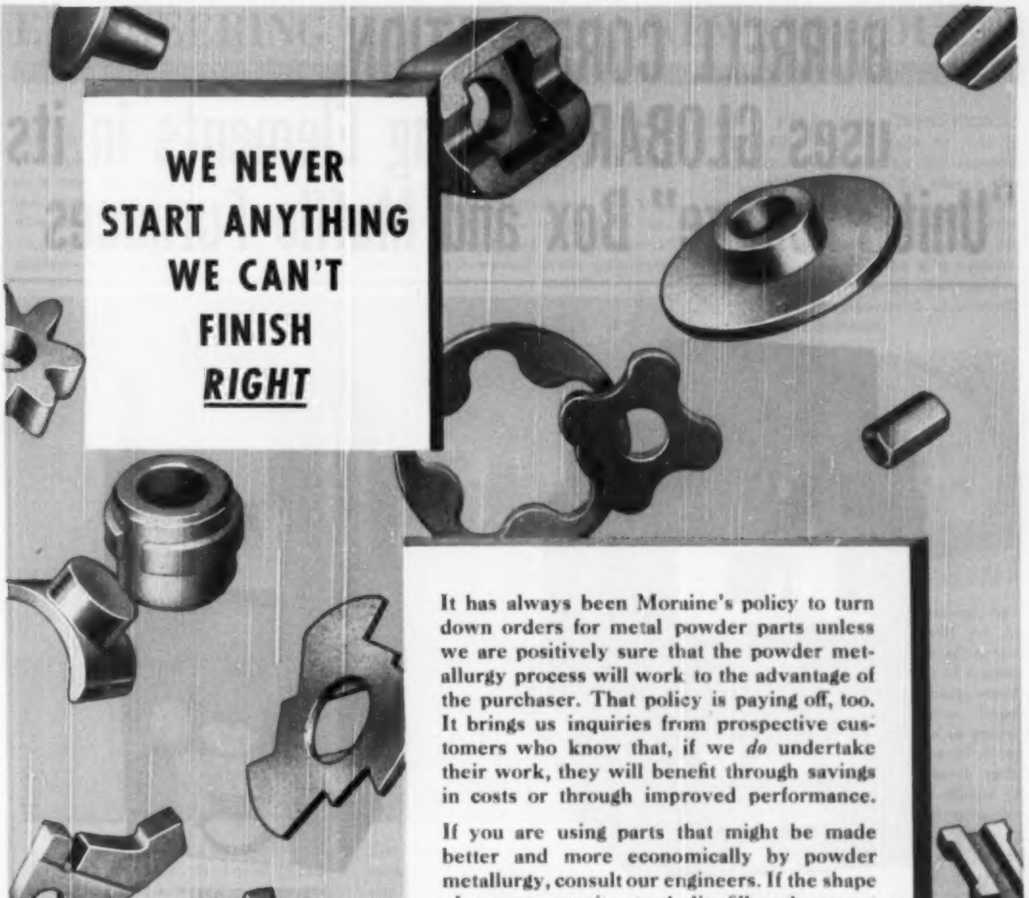
Gerald Capwell ⊕ has been transferred from the chemistry laboratory of the Chevrolet Motor Div.'s, Tonawanda, N. Y., plant to a supervisory position in the new laboratory at the Cleveland plant.

Capt. R. D. Fuller ⊕, formerly a teacher in the department of engineering at Ft. Scott, is now a student in the Guided Missiles School at Ft. Bliss, Tex.

Charles W. Andrews ⊕, formerly with Battelle Memorial Institute as a research engineer, has joined the development division of Brush Beryllium Co., Cleveland, as a metallurgist.

E. I. Bricker ⊕ has been granted leave of absence from Georgia Institute of Technology to work as an engineering designer in the Long Beach, Calif., division of Douglas Aircraft.

Robert E. Krueger ⊕, formerly a staff member at the Los Alamos Scientific Laboratory, has resumed his studies in mechanical engineering at Stanford University, Stanford, Calif.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If you are using parts that might be made better and more economically by powder metallurgy, consult our engineers. If the shape of a part permits good die fill and correct density . . . if its required physical properties and tolerances can be obtained by normal production methods . . . and if it is to be made in quantities sufficient to justify tooling costs . . . then, and only then, will we take on the job. And, even before we begin to produce, you can be assured of dependable results—for we never start anything we can't finish right.
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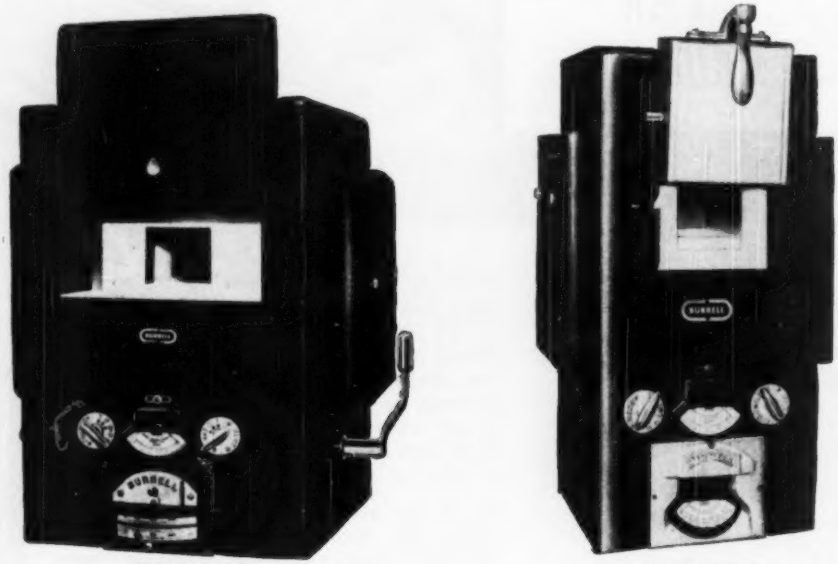

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GLOBAR heating elements offer several other important operating advantages. Convenient and simple to install, they eliminate the need to shut down a furnace when making replacements. Improved working conditions are realized through the absence of dirt and fumes. Explosion and fire hazards are eliminated. Electrical energy is converted into clean, radiant heat where you want it and in the proper amounts.

For more complete information on installation and operating details of GLOBAR heating elements, write Department X-20, The Carborundum Company, GLOBAR Division, Niagara Falls, New York.

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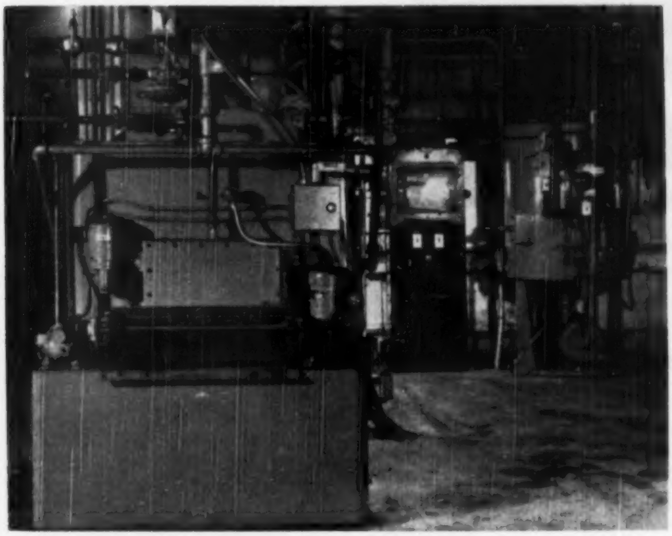
TRADE MARK

CARBORUNDUM

"Carborundum" and "Globar" are registered trademarks which indicate manufacture by The Carborundum Company

ENGINEERING DIGEST OF NEW PRODUCTS

ROTARY FLAME HARDENER: The development of a machine, designed on a new principle, for flame hardening gears, cams and wheels in all dimensions up to 36 in. has been announced by the Lakeside Steel Improvement Company.



According to the company the machine promises to revolutionize the method of case hardening gears, cams and wheels. Cost reductions, as against previous methods attempting to case harden the wearing surface only, have been greatly reduced and the control of the case depth has been brought to a peak of uniformity not possible under other methods of treating.

Named the Lakeside Radial Rotary Flame Hardener, the machine consists of a series of patented burners directed on the piece which is mounted on a motor driven spindle. The work spins at a determined rate of speed as it heats and as soon as the proper temperature is reached, the hydraulic mechanism submerges the work in a tank of water and oil while it is in a spinning motion.

With this arrangement, the time of heating and quenching has been cut considerably, and the hardness of material is increased to the maximum.

The special, patented burners fit the contour of the gears, cams or wheels and it is possible to increase or decrease the number of burners directed on the piece.

The time of heating and quenching depends entirely on the size. The present machine accommodates work up to 36 in. in diameter with a 4 to 5 in. face.

One of the most important features is the speed of heating and quenching. The positive assurance of uniformity and maximum hardness that can be obtained from the steel is also of prime consideration.

For further information circle No. 89 on literature request card on page 236B

DETERMINATION OF CHROMIUM IN STEELS: A new photometric method for the determination of Chromium in 18/8 and similar steels is announced by Fisher Scientific Company. The method's speed is derived from the technique of simply dissolving the steel and measuring the absorption directly, using the Fisher Electrophotometer. Nickel, the only interfering element, need not be chemically isolated since the judicial choice of a narrow band filter renders the interference negligible.

Bureau of Standards steels were determined with a standard deviation of $\pm 0.15\%$. The optimum range extends from 7% to 25%.

For further information circle No. 90 on literature request card on page 236B

DISC FILE FOR NONFERROUS METALS: A new type of disc file has been developed by Kennametal, Inc., which provides for faster, less costly operations on nonferrous metals commonly performed by grinding, such as snagging castings, cutting off flashing, facing and squaring up surfaces, etc. The expense involved in frequent replacement of abrasive wheels is eliminated.

Triangular prisms of strong, hard Kennametal (90.0 Rockwell A) are copper-brazed to the face of a steel back-up plate, in a number of courses, to form a multiplicity of sharp, sturdy cutting edges. They are so shaped, grouped, and positioned as to provide a 30° negative axial rake, a 30° clearance angle, and 10° negative radial rake. This construction affords the most efficient and free-cutting action. Material is removed in sizable chips—no abrasive dust. A remarkably smooth, true surface is produced. Eccentricity of the intermediate courses of prisms assures uniform cutting action across the face of a workpiece. When the file is run at proper speed, workpieces remain cooler than with abrasive wheels because chips dissipate the heat of cutting.

Four sizes are available, 6, 8, 10, and 12-in. diameters, priced at $107.00, $185.00, $255.00, and $325.00, respectively.

For further information circle No. 91 on literature request card on page 236B

SPECIAL CRUCIBLES AND BOATS: Availability of ceramic tubes, crucibles, and various other shapes in Magnesia, Beryllia, Zirconia, Thoria and Recrystallized Alumina is announced by the Laboratory Equipment Corporation. These materials are used for various special applications (up to 3000° C. or 5400° F.) where commonly available ceramics will not stand up.

For further information circle No. 92 on literature request card on page 236B

NEW PRODUCTS

HARDENING COMPOUND: A radical new method of case and depth hardening mild steel was demonstrated by Mr. Wilson and Mr. Necamp of the Wilson Carbon Company, Metalworking Division, at a recent technical conference.

Ordinary mild steel, in this case concrete reinforcing rod and common nails, was heated to a bright cherry red with a blow torch. The steel had been pre-shaped to form chisels and prick punches. After heating, the red hot steel was stirred into a can of "High-Speed-It" and the powder was allowed to fuse on the surface. The piece was then reheated to the same temperature (about 1500° F.) and quenched in cold water. The whole process was completed in from one and a half to two minutes. The tools thus hardened were then used to chip and punch cold-rolled steel and machine tool steel. No damage to cutting edges or points was apparent and the tools were found to be comparable in hardness, wear resistance and toughness to high speed tool steels. Microscopic examination of a section of the treated material is said to have shown the original metal to be covered by a hard, high-carbon surface layer about $\frac{1}{16}$ in. thick, supported by a sub-layer of tough, ductile carbon-chrome carbide, approximately $\frac{1}{32}$ in. thick.

This quick, economical method of treating low cost steel in order to obtain hard working surfaces with a tough sub-structure is believed to have wide application in making efficient cutting tools, dies and machine parts on the spot from the mildest steels.

For further information circle No. 93 on literature request card on page 236B

WELDRAWN TITANIUM TUBING: The Superior Tube Company has announced the limited availability of Weldrawn commercially pure Titanium tubing. Three standard tempers, annealed, half hard and hard drawn, are being offered.

Sizes which have been produced range from ¾ x .049 in. wall down to ⅛ x .010 in. wall. Intensive development work continues and it is expected that heavier wall thicknesses in the Weldrawn product and a line of seamless tubing will eventually be offered.

A technical data release giving analysis limits and mechanical properties is availble upon request.

For further information circle No. 94 on literature request card on page 236B

ENGINEERING DIGEST OF NEW PRODUCTS

CLEANING STEEL AND OTHER METALS: The classic method of cleaning steel and other metals in an acid bath may soon be completely outmoded according to the Hooker Electrochemical Company.

Virgo Salt, the registered trade name for the product, and the Hooker patented descaling process have up to the present been used in a relatively small number of commercial installations during the developmental stage. Over 20 different individual applications of the process are in use at the present time but current experimental work indicates that even more applications are possible.

The process makes use of a fused alkali bath followed by a water quench and a short acid dip for most applications. For stainless alloys a second dip in nitric acid is used to brighten and passivate the surface. The method is economical, simple and safe in operation. To date, over 16 different types of ferrous metals have been successfully descaled. Among these are high alloy steels, tool steels, cast iron and wrought iron. Any shape can be processed from rods, bars and wire to tubes, sheets and strips and even forgings, castings and fabricated parts. In some cases two jobs are done at the same time as for example the combined stress relieving and descaling of auto bumper brackets.

Although the process was originally developed for descaling stainless steel, it has since been found to be extremely versatile in its applications. In desanding castings for example, it completely removes the sand and exposes any pitting or pocketing due to faulty castings and thus eventually eliminates the high cost of too many rejects.

Generally speaking, the Hooker descaling process is applicable to any metal or alloy which is not attacked by molten caustic soda at 930° F. or whose physical properties are not adversely affected at this temperature.

The Virgo Salt bath method descales without pitting or loss of base metals. Mill scale, heat treating scale and rust are all converted to an acid soluble oxide. Acid consumption is relatively small and the Virgo Salt bath may be used for years with only small additions to replace drag-out. The time cycle is short, making possible the handling of more materials in a given time. The molten salt bath is an inert, quiet liquid which minimizes hazard in operating the process.

It is easy and economical to convert from conventional pickling methods to the Hooker process. For the Virgo Salt bath a mild steel tank is used and any of the three conventional methods of heating may be employed (external gas firing, immersion tubes of various types or immersion electrodes). Except for temperature controls, no auxiliary equipment is required. As a result many types of galvanizing or heat treating baths can be converted by simply removing the contents and charging with Virgo Salt. Other equipment required is relatively simple, consisting of a tank for water quench and an acid dip tank. For stainless steels a second acid tank for nitric acid dip is needed. For batch operations a traveling overhead monorail crane handles work from one tank to the next. The process is applicable to continuous work for strip wire and wire rod.

For further information circle No. 95 on literature request card on page 236B

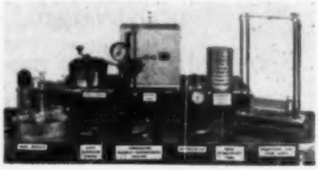
MERCURY THERMAL SYSTEM FOR HIGH TEMPERATURE APPLICATIONS: A newly developed 1200° F. mercury thermal system for industrial processing has been announced by Taylor Instrument Companies.

This new mercury thermal system provides simple, dependable and less expensive means of measurement and control of temperatures above the conventional 1000° F. indication. Such applications as gas-fired ovens, annealing ovens, high temperature blanchers, measurement of exhaust gases, etc., can be accurately served with this new measuring system.

Outstanding features include a newly developed Bourdon-type spring, type 347 stainless steel thermal element, compensation for varying case and ambient temperatures and uniformly graduated charts. Range spans of 1000, 600, and 400°F., or equivalent Centigrade, are available in all standard Taylor indicating recording and controlling instruments. No system can be furnished in which the range starts at temperatures below 700° F.

For further information circle No. 96 on literature request card on page 236B

FOUNDRY TESTING EQUIPMENT: A complete line of foundry testing equipment, developed by Harry L. Campbell, will be marketed by the Claud S. Gordon Company as the Gordon-Campbell Foundry Testing Equipment.



Each of these new testing units has been designed to conform with the recommendations of the Committee on Foundry Sand Research of the American Foundrymen's Society. Investigation has shown that the simplicity of the design and operation of these new testing units adds to the reliability of the results obtained.

While the line now consists of ten units covering the majority of the tests recommended by the Committee on Foundry Sand Research of the A.F.S., other units are under development and will be added from time to time.

For further information circle No. 97 on literature request card on page 236B

ARC-WELDING ELECTRODE: A new improved arc-welding electrode, the W-22 (AWS Class E 6010), a reverse polarity d-c rod, has been announced by General Electric's Apparatus Department.

The W-22 electrode is designed specifically for vertical and overhead welding of all types of joints in mild steel. Because of its penetrating arc the W-22 is suited for welding galvanized plate stock. This penetration also facilitates the welding of lap joints and edge welds.

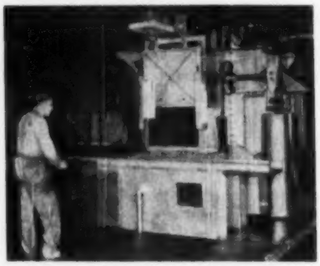
High tensile strength and dutiiity with good impact resistance are featured properties of the W-22 electrode welding bead. The new electrode may be used for the repair welding of castings, because of its low volume slag-forming characteristics.

The stable arc produces weld deposits of very smooth contour in horizontal and overhead positions without the necessity of oscillation.

For further information circle No. 98 on literature request card on page 236B

ENGINEERING DIGEST OF NEW PRODUCTS

BATCH-TYPE FURNACE: After extensive engineering development and field test work, Surface Combustion Corporation announces its new high production batch-type furnace for all types of control atmosphere heat treatment of steel. The furnace is available with the built-in RX atmosphere generator to provide for gas carburizing, homogeneous carburizing, dry (gas) cyaniding and carbon restoration, clean hardening and general heat treating. Work is carried in and out of the furnace on four trays which are moved by alloy screws. A lowerator quench mechanism is included which provides "semi-automatic" operation for the charging and discharging of the furnace.



Extremely fast heating rates developed by the use of radiant tube firing, combined with a fan to circulate heated, prepared atmosphere, provide production up to 200-pound-per-hour gross loads per square foot of area. The furnace has a maximum gross charge capacity up to 2500 pounds, depending upon the type of work to be processed.

Floor space requirements of this furnace are extremely low in view of its production capacity. With the RX atmosphere generator built integrally into the furnace unit, a 16 ft. long by 9 ft. wide space is adequate for the entire furnace.

Operating reports to date indicate the unit's capacity for light case cyaniding at less than one half cent per pound of work exclusive of burden and fixed charges.

For further information circle No. 99 on literature request card on page 236B

DUCTILE CECOLLOY: The Chambersburg Engineering Company is now producing large and small castings of Ductile Cecolloy for component parts of many Chambersburg products and is also marketing the material in the heavy jobbing casting field.

After more than four months of development work, Ductile Cecolloy castings, weighing up to 40,000 lbs., have been successfully produced.

Ductile Cecolloy is a high-carbon cast iron, treated with magnesium to transform the graphite from the normal flake form to spheroidal form, thus retaining self-lubricating properties and much of the vibration-dampening properties of cast iron, while virtually eliminating the inherent weakness of normal cast iron which results from the notch effect of flake graphite. The metallic matrix of the material is essentially steel, which can be produced with appropriate microstructures to give desired physical properties. It is also subject to heat treatment for alteration and improvement of physical properties.

Ductile Cecolloy can be produced to specifications within the ranges of the following physical properties as cast: Tensile strength 60,000 to 80,000 psi. Yield strength 40,000 to 60,000 psi. Elongation 0 to 15%. Modulus of elasticity 22,000,000 to 25,000,000 psi.

Although higher in cost than cast iron, Ductile Cecolloy is lower in cost than cast steel. Weight reduction made possible by its high strengths will in many cases result in economies over cast iron construction, and further economies will result from its substitution for cast steel where physical properties permit.

Machinability is equal to or better than cast steel and fine finishes are easily attained, thus resulting in cost savings and enhancing the wear resistant properties.

For further information circle No. 100 on literature request card on page 236B

DIE CASTING MACHINE FOR ZINC: The new HP-1-Z zinc die casting machine has been specifically designed to meet the needs of the zinc die caster, according to Lester-Phoenix, Inc. This machine was designed to eliminate as far as possible, the human element in setting up and adjusting the machine.

The gooseneck locates itself in two machined slots in the yoke. Misalignment is impossible. Fixed to the gooseneck is a split bronze bushing which guides the plunger stem, so misalignment is impossible here, too. The head of the plunger is held by a T-slot coupling attached to the plunger cylinder, making the plunger completely self-aligning.

The only adjustment is with two dog point screws against the bracket, seating the gooseneck firmly against the nozzle. The whole installation is simpler than setting up dies.

Another feature of the machine is that the pot can be made any size desired, since it is entirely separate from the structure of the machine itself.

Furthermore, the plunger cylinder yoke is no longer subject to any adjustment, being rigidly mounted on the frame of the machine. The oil lines to and from the plunger cylinder are permanent, rigid pipe lines, rather than hose, being considerably safer.

For further information circle No. 101 on literature request card on page 236B

PORTABLE RADIATION DETECTOR: A new portable radiation detector, the long-probe Gamma Survey Meter, which enables the operator to measure radioactivity from a distance has been announced by the Special Products Division of the General Electric Company.

The new instrument, developed by the G-E General Engineering and Consulting Laboratory, can be used for monitoring areas in which radioactivity is suspected or for other types of radiation metering.

A detector located at the tip of a four-foot-long probe converts radioactive emanations into electrical energy. This detector consists of an electronic tube and phosphor, a material which gives off light in the presence of radioactivity. Light from the phosphor acts upon the electronic tube, which converts the light energy into electrical energy and amplifies its magnitude.

At the other end of the instrument, a dial is activated by amplified energy from the tube. It registers the amount of radiation exiting the phosphor four feet away. The detector is powered by 1000 volts induced from low-voltage batteries, which are enclosed in a box that can be carried over the operator's shoulder

For further information circle No. 102 on literature request card on page 236B

NEW PRODUCTS

ELECTRIC HOT PLATE: A new Temco electric hot plate which is unusual in design and performance is announced by Thermo Electric Manufacturing Company.

An extremely sensitive but sturdy thermostat provides completely variable control from 100 to 700° F. (38 to 370° C.). Temperature variation is held within 5° at 100° F. and within 2° from 200° F. to maximum. This sensitivity of control is unusual, particularly in the lower temperature ranges, and makes the plate adaptable to many critical uses as well as for general heating. The control dial is numbered to indicate approximate temperature settings. A neon indicating light glows while the plate is heating.

The cast aluminum surface plate heats fast and evenly. Its square shape, 6 x 6 in., permits greater usable surface area. It is well insulated on the bottom side and is mounted within the metal body with only four small points of contact to minimize heat conduction to the body. Heating elements are made from highest quality nickel-chromium alloy. Thermostat contacts are high grade silver and of large diameter for cool operation.

For further information circle No. 103 on literature request card on page 236B

CONTROLS: Two new instruments—one a completely redesigned millivoltmeter-indicating controller to be known as the Pyr-o-Vane controller, and the second a Protect-o-Vane controller designed to protect a furnace, oven or a process from excess temperatures—are being introduced by Brown Instruments division of Minneapolis-Honeywell Regulator Company.

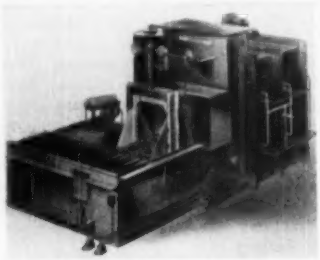
Automatic control provided by the Pyr-o-Vane controller is effected by a light metal vane which moves in and out of an electrical field.

The Protect-o-Vane is described by the company as a companion piece for the Pyr-o-Vane controller, many of the components being interchangeable. It shuts off heating sources when temperatures go beyond a set limit. It can also be used in conjunction with the company's ElectroniK line.

For further information circle No. 104 on literature request card on page 236B

NEW PRODUCTS

CONTROLLED ATMOSPHERE FURNACE: A new controlled atmosphere furnace capable of dry cyaniding, light case carburizing, and clean hardening is designed with a specific view to lower costs of operation and maintenances according to Industrial Heating Equipment Company. Among the features of these furnaces are: high convection for fast heating, positive passage of atmosphere through the work, simplified construction of alloy components, trays designed especially for quenching.



Fans and Radiant Tubes are mounted for easy accessibility when maintenance is required. Generator is separate from furnace, but close coupled so the generated gas does not cool and reverse chemically before entering the work chamber. Furnace illustrated quenches through air which permits water quenching or martempering. The units are also supplied with vestibules for quenching from gas atmosphere.
For further information circle No. 105 on literature request card on page 236B

VERSATILE LOW COST UNIVERSAL TESTING MACHINE: Standard tensile, compression, and transverse tests on metals, spot welds, rivets, insulating and sheet materials, wire and plastics can be made accurately on the new LC Type Machine and Tools developed by Tinius Olsen Testing Machine Company.

This new low-cost unit is extremely simple in design and operation. It is compactly and ruggedly constructed and offers industry and educational institutions a practical and convenient machine to supplement high precision testing equipment for production and quality control testing.

Provided with dual capacity ranges of 10,000 pounds and 1000 pounds, the machine is guaranteed to meet Army, Navy, Federal and ASTM specifications. Available in both hand operated and motor driven models.
For further information circle No. 106 on literature request card on page 236B

107. Abrasive Wear

Six-page bulletin, "How to Reduce Abrasive Wear with Thermalloy HC-250", describes the physical properties of the thermalloy HC-250 and lists the many uses and advantages of this exceptionally abrasive-resistant metal. *Electro Alloys Div.*

108. Alloys, Bronze

New catalog entitled "Bronze and Copper Bearings and Castings" gives physical properties and comparative specifications for 27 different bronze alloys and 5 aluminum and manganese bronzes. *American Brake Shoe Co., National Bearing Div.*

109. Alloys, Fabricated

New catalog is available, showing cost-cutting fabricated heat treating equipment for higher pay loads and better quality. *Rolock, Inc.*

110. Brazing

Easy-Flo simple, versatile method of fabricating ferrous, nonferrous and dissimilar metals is described in bulletins 12-A and 17. *Handy & Harman.*

111. Carbide Application

New useful chart of all tungsten carbide manufacturers' grade recommendations for chip removal, wear, and impact applications. Prepared by recent survey of the Carbide Industry, it features a new symbol code to simplify inventory and purchasing problems. *Adamas Carbide Corp.*

112. Carbon Analysis

Bulletin 910 describes new electronic method of carbon analysis for steel and cast iron. *Lindberg Engineering Co.*

113. Carburizing-Martempering

Article entitled "Carburizing-Martempering Procedure Streamlines Crankshaft Heat Treating" covers technique employed in combining liquid carburizing and martempering in a single heating operation. The economies effected are compared with the heat treating process replaced. *Ajax Electric Co.*

114. Castings

New 16-page booklet discusses metal specifications, chemical properties and physical properties of a series of carbon and alloy steels from normal carbon steel through various combinations of chromium, molybdenum and other types of alloy steels. *Dodge Steel Co.*

115. Castings

For complete information on difficult casting problems send for the "Book of Facts" on magnesium, aluminum and bronze castings. *Eclipse-Pioneer Division Foundries.*

116. Control, Quality

Bulletin 41 describes new universal testing machine for low-cost industrial production and quality control, laboratory, educational, and shop testing of metals. *Tinius Olsen Testing Machine Co.*

117. Coatings, Metal

Explanations of high-vacuum evaporation of metals and other solids set forth in detail in new 12-page booklet, "Vaporized Metal-Coatings by High Vacuum". *Distillation Products, Inc.*

118. Control Equipment

12-page folder deals with two different, complete high-temperature testing laboratories for determining the physical properties of molding materials. Also contains technical data and high temperature properties of molding materials. *Harry W. Dietert Co.*

119. Controller

Write for Specification sheet 112 illustrating new Pyr-o-Vane millivoltmeter controller. It is electronically controlled, plugs in and is immune to ambient temperature changes. Also features fail-safe design and thermocouple burn-out for protection of work load. *Brown Instrument Co.*

120. Conveyor Belts

Illustrated booklets, sent on request, describe conveyor belts designed for use in innumerable industrial applications. *Wickwire Spencer Steel Div.*

121. Copper Sheets

New 23-page booklet, the product of a ten-year program of design development and test combined with field investigations, contains complete, detailed specifications for all types of sheet metal installations employing copper. *Revere Copper & Brass, Inc.*

122. Cut-Off Machines

New bulletin describes advantages in performance of new AB cut-off machines in metallurgical laboratory. *Buehler, Ltd.*

123. Die Blocks

24-page booklet on "Finkl Quenched and Tempered Die Blocks" tells about four types of Finkl die block steel, how to select the right one for your job, how to make your dies last longer, and many other interesting and helpful facts. *A. Finkl & Sons Co.*

124. Extrusions

"Alcoa Aluminum Impact Extrusions" is the title of a new booklet giving up-to-date information on short-cuts to designing all types of parts by means of these new impact extrusion presses. *Aluminum Co. of America.*

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

125. Fastening Specialties

New 28-page manual features full descriptive and engineering data on the broad range of Southco blind rivets, anchor nuts, panel fasteners, door-retaining springs, etc., and various newly-developed items. *South Chester Corp.*

126. Films and Plates

Special sensitized plates and films for the scientific and industrial laboratories are described in a new 8-page booklet issued by the Eastman Kodak Co. *Eastman Kodak Co.*

127. Finishing

Special zinc phosphate coating chemicals provide excellent surfaces for paint-bonding, rust-proofing and drawing. *American Chemical Paint Co.*

128. Fittings, Stainless

New informative technical bulletin, "Newscast", features reviews of technical literature, questions and answers culled from service engineering files. *Cooper Alloy Foundry Co.*

129. Forgings

New catalog 51 contains 30 pages covering such topics as type of forgings; where and how to use forgings; turnbuckle dimensions, strengths and related data; clevis nut data; and eyebolt sizes, types, etc. Well illustrated with tables, drawings and photographs. *Merrill Brothers Co.*

130. Free-Machining Bar Steel

Reprint of article entitled "La-Led, A New Free-Machining Bar Steel" by Glenn D. Bayer, Metallurgist at LaSalle Steel Company, discusses the advantages and characteristics of the new steel. *LaSalle Steel Co.*

131. Furnaces

Bulletin 815-AB gives details for increased production economy with reciprocating furnaces. *American Gas Furnace Co.*

132. Furnaces

New illustrated folder gives a complete description of special atmosphere furnaces for sintering metal powder products and other processes. *Electric Furnace Co.*

133. Gas-Cutting Guide

Pocket-sized oxyacetylene machine gas-cutting guide has now been reprinted. By means of a handy slide-rule type of chart, tip numbers are indicated, and oxygen and acetylene pressures, speed in inches per minute, gas consumption and approximate width of kerf are all easily read down one column. Cleaning drill sizes are also indicated. *Air Reduction Sales Co.*

134. Gas Generator

Bulletin 1-11 describes new inert gas generator Model 1 MIHE, rated at 1000 c.f.h., obtains the same analysis of inert gas regardless of demand. Fully automatic, it gives accurate proportioning and assures precise analysis over full operating range. Ratio control adjusts for manufactured, natural, propane, butane or refinery gases. *C. M. Kemp Mfg. Co.*

135. Grinding and Polishing

4-page pamphlet gives facts about backstand belt grinding and polishing. *Armour & Co.*

136. Grinding Jig

New 4-page brochure entitled "Kennametal Machine Bit Grinding Jig" describes and illustrates grinding of bits for mining machinery. *Kennametal, Inc.*

137. Hardness Testers

Bulletin DH-114 contains full information on Tukon hardness testers for use in research and industrial testing of metallic and nonmetallic materials. Also included is bulletin DH-7, giving experiences in various fields. *Wilson Mechanical Instruments Co.*

138. Heat Resisting Alloys

Monthly warehouse stock list of heat resisting alloys in sheets, plates, rounds, squares, angles and many other forms lists typical proven applications, physical properties. *Rolled Products Div., Michigan Steel Casting Co.*

139. Heat Treating

Attractive new booklet, "The Science of Gas Chemistry for Heat Treating", Form SC-129, gives complete details of applications for prepared gas atmosphere compositions and costs. *Surface Combustion Corp.*

140. Heavy Duty Forgings

16-page booklet on "Heavy Duty Forgings". Profusely illustrated, it shows forgings of all sizes in every phase of development from ingot to finished product. *A. Finkl & Sons Co.*

141. Induction Heating

Learn the many advantages of applying Tocco induction heating for hardening, brazing, soldering, annealing or forging operations. Send for free booklet now available. *Ohio Crankshaft Co.*

142. Industrial Planning

New book 127 tells how you can share in a "round-table" discussion of planning expansion, remodeling or modernization of your plant. *Continental Industrial Engineers, Inc.*

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

143. Ingot Casting Machine
4-page brochure illustrates and describes the Buhler ingot-casting machine Type GNM. In this machine the work of ladling the metals from one furnace to another, and from the furnace into the ingot mold, and also the emptying of the molds, is all performed mechanically. *Buhler Brothers, Inc.*

144. Laboratory Technique
"The Laboratory" vol. 19, booklet published periodically for those interested in keeping informed on the latest developments of laboratory apparatus and techniques. *Fisher Scientific Co.*

145. Load Testing
Bulletin 307 describes Type "C" SR-4 load cells, in which strain gages bonded to a column are load-sensitive elements. Cell capacities from 2000 to 200,000 lb. in seven sizes. Particularly useful in tank weighing. *Baldwin Locomotive Works.*

146. Lubrication of Hot Metals
New bulletin 426 describes how (DAG) colloidal graphite can solve your lubrication problems in hot metal forming operations. *Acheson Colloids Corp.*

147. Machine Design
Fundamentals of producing low-cost machine parts — design, material and treatment — are discussed in new 72-page "Three Keys to Satisfaction". *Climax Molybdenum Co.*

148. Metal Cutting
Catalog N-3 is a beautifully illustrated book containing clear photographs and full specifications of the complete line of shapers, shears and brakes for all types of metal cutting operations. *Cincinnati Shaper Co.*

149. Metal Treating
16-page ready-to-file data folder gives technical information on metal treating and finishing products. *Healbath Corp.*

150. Metalworking Data File
Finger-tip reference file 501 contains engineering information about equipment and processes used for metal stampings, heavy weldments and pressed steel shapes. *Chas. T. Brandt, Inc.*

151. Microcastings
This 16-page booklet describes many applications for microcastings and also explains the process itself. *Microcast Div., Austenal Laboratories.*

152. Nickel Alloys
"Nickel Alloy Steel Castings in Industry" provides valuable information for designers and users on many adv tages of cast nickel alloy steels. *International Nickel Co.*

153. Oil Burner
New 24-page catalog 410 describes the Hauck proportioning oil burner. A precision instrument for better combustion, more accurate control of furnace temperatures and atmosphere. *Hauck Mfg. Co.*

154. Oil, Quenching
Catalog V-1146 gives detailed information on self-contained oil coolers, together with easy selection tables. *Bell & Gossett.*

155. Oils, Cutting
Interesting facts on how shop operation can be more efficient and economical through the use of right lubricants described in "Metal Cutting Fluids". *Cities Service Oil Co.*

156. Petroleum Refining
New booklet now available on Allegheny clean, sound, sanitary fittings for petroleum refining industry. Others in different fields furnished on request. *Allegheny Ludlum Steel Corp.*

157. Polishing and Buffing
Bulletin entitled "Acme Straightline Automatic Polishing and Buffing Machines" illustrates and describes a machine for every type of production polishing and buffing job. *Acme Mfg. Co.*

158. Potentiometer, Portable
Bulletins 270 and 270-A describe portable potentiometers in a selection of ranges up to 1.6 volts. *Rubicon Co.*

159. Potentiometers
Dynalog instruments for control of temperature, humidity, pressure, flow, etc. Details in bulletin 427. *Foxboro Co.*

160. Pressure Vessel Accessories
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New 24-page booklet, "How to Specify and Buy Alloy Steel with Confidence", emphasizes the importance of careful selection, positive knowledge of properties and accurate heat treatment in purchasing alloy steels. *Jos. T. Ryerson & Son, Inc.*

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12-page booklet on stainless steel bars entitled "Widest Range of Sizes, Highest Standard of Quality" illustrates modern production methods and discusses the principal grades, characteristics and uses of stainless steel. *Carnegie-Illinois Steel Corp.*

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METAL PROGRESS

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February, 1950

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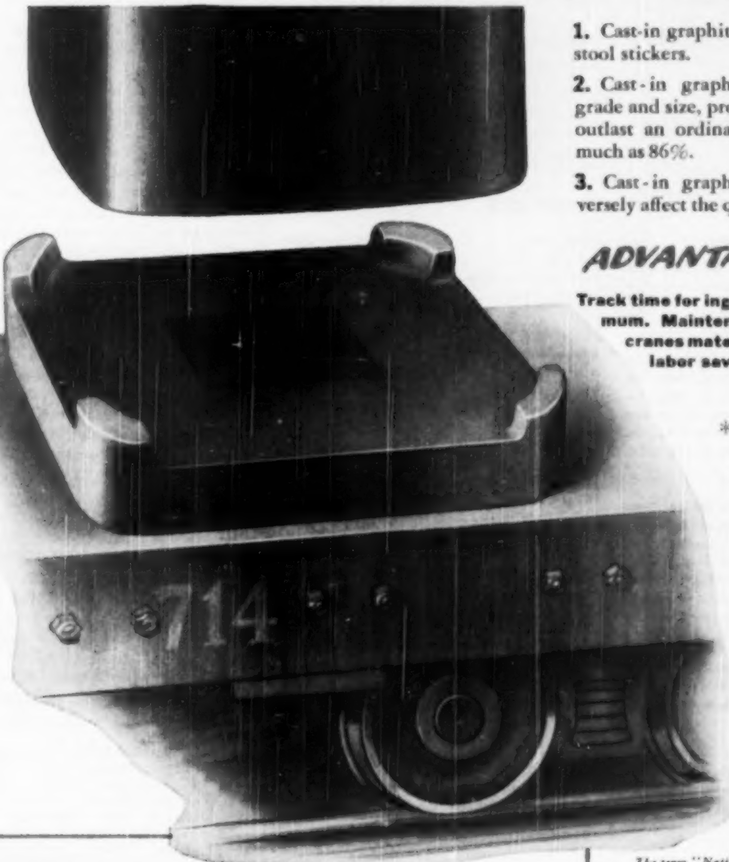

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Cold Welding*

WHEN METALS are welded at temperatures below the solidus, pressure must be applied at fairly high intensities. The metal deforms locally, the amount depending on temperature and the hardness of the metal, as well as on the pressure. One fundamental advantage of "cold" welds is the avoidance of cast metal and the "overheated" zone in fusion welds.

In a series of studies on light alloys of aluminum and magnesium conducted by R. F. Tylecote both heat and pressure were applied simultaneously through dies to make lap welds in thin sheet metal. Pressure-butt welds between ¾-in. bars were also studied.

For making lap welds, dies of either tungsten-copper alloy or heat resisting steel were supported in a core block of aluminum bronze and heated by a resistance coil. Pressures up to 120,000 psi. and welding temperatures up to 925° F. were used, producing deformations or dimples at the weld as deep as 80% of the total thickness of metal. The average welding range for the materials and thicknesses used was about 660° F. and 30,000 to 60,000 psi., with deformations (dimples) of 40 to 60%. With high pressure (120,000 psi.) welds were obtained in some alloys at 200 to 400° F. The strength of a weld made at any specific temperature depends largely on the deformation obtained when the weld was made; as the welding temperature is lowered the deformation necessary to produce a weld increases.

Cleaning of the aluminum or magnesium sheet is very important. The best method was scratch brushing just before welding, to break the oxide film and roughen the surface. Pickling alone was not effective. A normal welding cycle involves a "heating-up" time of about 2 min. and a "welding" time of about 3 min., although welding times up to

(Continued on p. 240)

*Abstracted from "Pressure Welding of Light Alloys Without Fusion", by R. F. Tylecote, *Transactions*, British Welding Research Assoc., November 1945, p. 163; "Further Investigations on the Pressure Welding of Light Alloy Sheet", by R. F. Tylecote, *Transactions*, British Welding Research Assoc., November 1948, p. 94r; "The Pressure-Butt Welding of Light Alloy Bar", by R. F. Tylecote, *Transactions*, British Welding Research Assoc., February 1949, p. 2r; "Solid-Phase Bonding of Aluminum Alloys to Steel", by V. W. Cooke and A. Levy, *Journal of Metals*, November 1949, p. 28.

Cold Welding

(Starts on p. 238)

15 min. were used. At the higher temperatures the welding time is shorter, and at 900° F. the weld strength in aluminum alloys increased with deformation and welding time.

Maximum weld strength was usually developed with 40 to 60% deformation. (Sometimes higher strengths were obtained with greater weld deformations but in any event sheet thickness has a pronounced effect due to stiffness.) A hard rolled aluminum-manganese alloy similar to 3S-H gave best weld strength over a wide range of welding temperatures. "Cold" pressure welds are lower in shear strength than with conventional spot welds in these sheet materials. This is attributed to two factors — a plug is more readily pulled out, particularly in deeply dimpled welds, and erratic bonding and sheet distortion due to use of conical dies. The pressure welds showed considerable scatter in strength properties.

In a second study cylindrical dies were used together with shim-stops to limit deformation of the weld area. Welded specimens were much flatter and dimples could be maintained constant to ± 1%. These dies gave consistently higher strengths at deformations of 20 to 60%. With a 0.45-in. die, pressure welds in 0.05-in. alclad duralumin were equivalent in size and strength to conventional spot welds.

It was found that high-purity aluminum sheet could be pressure welded at room temperature with pressures as low as 40,000 psi. and deformations of 40 to 60%, and these welds were from 80 to 85% as strong as those made with similar deformation at 650° F.

The strength of welds in magnesium showed considerably more scatter than those in aluminum, which is attributed primarily to the difficulty of preparing the surface. Fairly good results can be obtained by power scratch brushing. Interposing commercially pure magnesium foil 0.004-in. thick between the surfaces gave weaker welds and more scatter.

Heat treatment after welding gave variable results; metallographic examination disclosed no evidence of grain growth across the weld line.

For most of the tests the time interval between scratch brushing and welding did not exceed 15 sec.; however, welds made with up to

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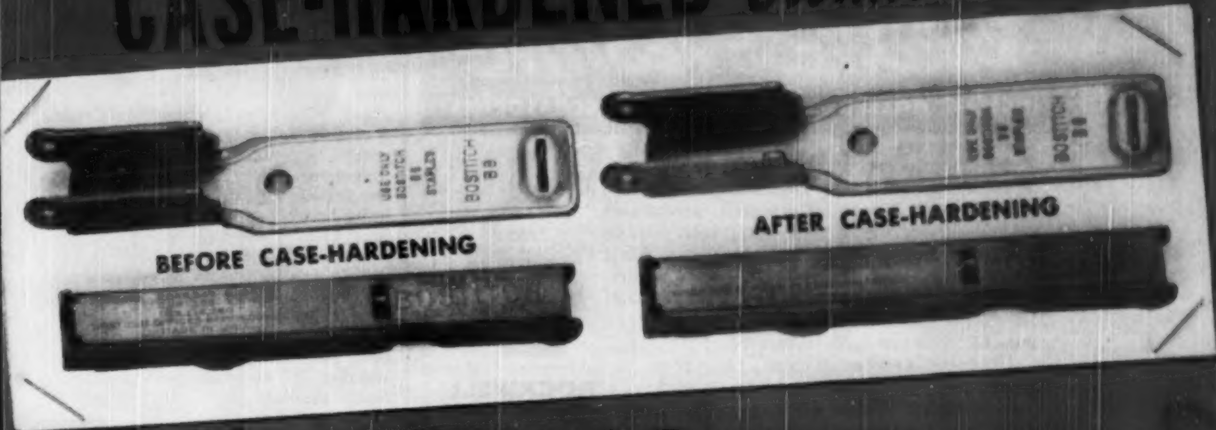

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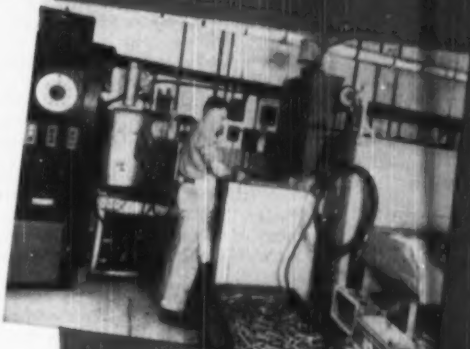

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ELECTRIC CERTAIN CURTAIN FURNACES

Cold Welding

(Starts on p. 238)

100 hr. delay were markedly weaker in commercially pure aluminum and aluminum-magnesium (7%) sheet. Heating a cleaned surface for 5 min. at 750° F. also impaired the results except in an aluminum-magnesium-silicon alloy. Generally the exposure time at room temperature between cleaning and welding must be very short.

Weldability of these alloys appears to be a function of recrystallization temperature and cleanliness. The inherent strength of the alloy also influences weld strength. However, no evidence was obtained that welding by recrystallization occurs under pressure at the higher temperatures. Some welds were obtained at temperatures well below the recrystallization temperature (under exceedingly high pressures and deformations). Prior cold working appears to have no particular influence. Welds were produced with deformations as low as 20%, and the minimum pressure required for these alloys lies between 2000 and 14,000 psi. It would appear that this type of welding for lap joints may be applied advantageously to assemblies having considerable welding in relation to their size.

To obtain more precise data on mechanical strength, welds were made between abutting ends of ¾-in. rounds of aluminum and magnesium alloys of various strength levels. The bars were butted vertically in a 10-ton hydraulic press, and heated with an oxy-acetylene ring burner. Abutting ends were of three forms: *(a)* machined to a ½-in. cylinder ⅝ in. long; *(b)* original diameter of bar; *(c)* tapered to ½-in. diameter in ¾ in. Machined and cleaned bar ends were power scratch brushed before abutting.

Welds were made by both the "constant temperature" and "constant pressure" methods. In the first technique an initial pressure of 12,000 psi. was applied and the burner lit, the flame controls having been previously adjusted from dummy experiments. Welding temperature was reached in 30 to 60 sec. when the flame was cut off and the desired upset pressure applied. In the second technique the desired welding pressure was applied before the start of heating and maintained throughout; heating continued until the bar ends were upset as desired. In practice this second method is

(Continued on p. 244)

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THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY

Cold Welding

(Starts on p. 238)

simpler, since no temperature measurements are necessary.

Welding specimens were then machined to 0.4-in. diameter for 2½ in. For bend testing, the specimens were machined to 0.60 in.; test supports were 6 in. apart and the bars were loaded at the third points (2 in. apart).

Contact areas in the tapered-end pieces *(c)* had the greatest temperature differential, and longer heating times are required to equalize temperature over the contact area.

Welds made by the "constant temperature" method using the *(c)* bar gave higher tensile strengths than welds made using the *(a)* bar if the contact areas increase up to 150% by upsetting. Above 150% upset the *(a)* bar gave higher strengths. This is possibly due to an outer zone of relatively high strength metal in the *(c)* bar's weld which has been worked at higher temperature than the central portion. As the amount of upset increases this outer metal is pushed further from the center and more of it is machined off the test specimen. Such a zone appears to be peculiar to the conical *(c)* bar welds; Tylecote believes successful pressure-butt welds require the smallest temperature gradient across the contact area.

Maximum tensile strengths of weld were obtained with section-area increases (upsets) of 200 to 400% using the cylindrical *(a)* bar and welding temperatures of 850 to 1100° F. With the conical *(c)* bar, bend fractures show no appreciable deformation in welds made with upsets below 300%; above this the angle of bend increases very rapidly. Contrary to lap welds, microexamination gave some evidence of grain growth across the weld line of these butt welds.

The "constant pressure" method does not produce as high or consistent weld strengths as at "constant temperature", which indicates the general principle that "for satisfactory pressure welding of light alloys, deformation of the interface under a small but significant pressure and over a narrow temperature range is necessary".

Application of high pressures in butt welding is extremely difficult due to the freedom of the interface to deform, yet weld strength is a function of deformation rather than pressure. Pressure for a good weld

(Continued on p. 246)

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Cold Welding

(Starts on p. 238)

need be only sufficient to hold the interfaces in intimate contact and to exclude air, provided that it imposes the necessary amount of deformation to break up the oxide film. The most weldable alloys are the Al-Mn and the Al-7% Mg alloys. The least weldable are the magnesium-base alloys. Optimum welding temperatures vary from 790 to 1100° F. for the various alloys.

Aluminum to Stainless — Experiments on the bonding of aluminum to 18-8 stainless are reported by Cooke and Levy. Annealed bars of 1-in. diameter were butted end-to-end under 5000-psi. pressure at various temperatures in a special aligning jig and twisted 180°. Pressure was maintained until 500° F. was reached, then reduced to 1500 psi.; this pressure was maintained until desired bonding temperature was reached, then increased to the desired value, and simultaneously the steel bar was twisted 180°. Pressure was applied continuously to compensate for upsetting. Welded specimens were cooled to 500° F. in the jig.

Experiments were made by axial pressure, wherein the hot metal was restrained in a sleeve of hardened high speed steel. In these tests 2500-psi. pressure was maintained during heating to bonding temperature, and then was increased as desired, held for 5 min., after which specimens were cooled and removed from the dies for heat treatment.

Surface preparation for twist bonding was as follows: Aluminum was ground on a 50-grit belt, or etched deeply with 20% sodium hydroxide. Anodic etching of the stainless resulted in best bond strength. Tensile strengths of 20,000 to 35,000 psi. were obtained with a range of bonding temperatures from 550 to 750° F. Subsequent annealing at 850° F. increased these strengths about 5000 psi. Bonding pressures of 12,000 to 13,000 psi. were used up to about 700° F. without excessive upsetting of the aluminum.

In the hot pressing with restraining dies the required bonding temperature appeared to be an inverse function of pressure. For example, at 850° F. at least 10,000 psi. was necessary; at 650° F. at least 30,000. The range of tensile strengths was approximately the same as that in twist welding. Heat treatment improved the bond strength, particularly of welds made

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Cold Welding

(Starts on p. 238)

by hot pressing in restraining dies. The mechanism of this improvement is not known but relief of residual stresses is one possibility; diffusion between iron and aluminum, aided by recrystallization, is a strong supposition; formation of a thin film of a submicroscopic iron-aluminum alloy is another possibility. The surface of the aluminum must be properly roughened for best bond strength in pressure welding, as was also observed in the British work.

Cooke and Levy point out that "hot-press bonding with no external lateral movement is believed to be a new feature in the solid-phase welding of aluminum to steel. The absence of external movement makes the technique quite practical for any part adaptable to press forging. A third feature is the ability to bond aluminum to stainless steel despite the presence of controlled oxide films. This is somewhat contrary to established ideas on pressure welding.

From the British work with pressure-butt welds in aluminum alloys it is concluded that sufficient lateral deformation to break up the oxide film is necessary. In the American work with welds between aluminum and steel the oxide film is not broken up by lateral deformation, which is nil; the oxide is retained and is made to improve bond strength in some way by post heat treatment. The effective ranges of bonding temperatures and pressures are higher in the British work than in the American.

W. L. WARNER

Cobalt*

COBALT is a metal in scant supply among North American ores. In the past surprisingly little attention has been paid to its chemistry and metallurgy. This first-rate monograph fills an important gap in both these fields. The author serves as chief research chemist for the major producers of cobalt and has been able to supplement information in the literature with data obtained at first hand.

Three quarters of the world's

(Continued on p. 250)

*A review of "Cobalt", by Roland S. Young, American Chemical Society Monograph 108, published by Reinhold Publishing Corp., New York, 1948. 181 p. ($5.00)

Cobalt

(Starts on p. 248)

cobalt comes from Africa at the present time and more than three quarters of the cobalt mined is used in the metallic state. None of the American ores is high grade and almost all that is used in this country is imported. The price of the metal is slightly under $2.00 a pound in small lots.

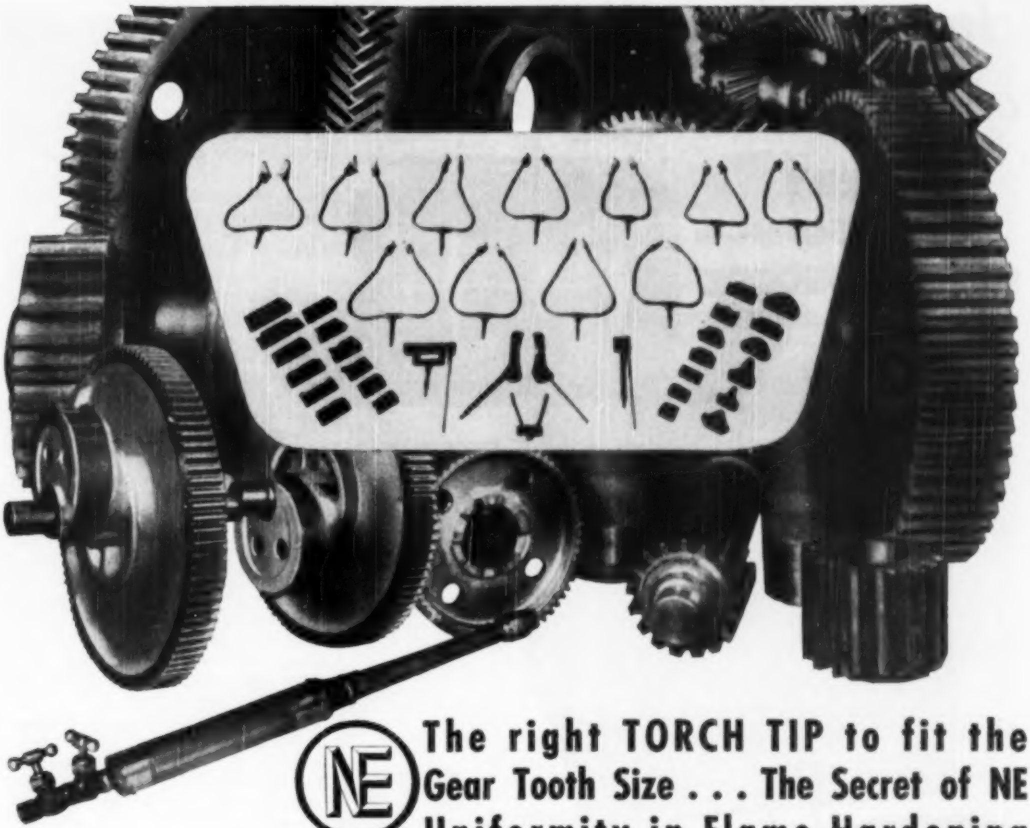
Few base metals require such a wide variety of metallurgical extractive operations as does cobalt; the methods vary greatly from ore to ore. Rondels are produced by pelletizing hydrated cobalt oxide, extracted from the ores, with 10% of pulverized wood charcoal and a binder such as dextrin, and after they have been dried, are reduced with charcoal or graphite in small reverberatory furnaces at 1925° F. From cobalt-nickel ores, the final rondel contains 97 to 97.5% Co with 1 to 1.5% Ni. The author believes that, in the future, electrolytic cobalt with a purity of 99.5% will gradually displace the rondels from the market. At the present time, it is not easy to procure high-purity cobalt in the United States, even for research purposes. Experimenters are driven to purifying their own supplies. This situation should be corrected.

Except for the complex cobalt ammines, only seventeen types of chemical compounds are discussed in a section entitled Chemical Properties of Cobalt. There has been no attempt to compete with the standard chemical texts, such as Mellor, on the innumerable coordination compounds of cobalt, but the typical ones are cited from a thoroughly modern viewpoint. The position of cobalt salts in catalysts for the Fischer-Tropsch synthesis of hydrocarbons and other syntheses is competently covered in a separate chapter. The role of cobalt in animal nutrition is also thoroughly up to date. The final chapter devotes 18 pages to analytical procedures for determining cobalt.

About one third of the book is concerned with the physical and mechanical properties of the pure metal and its alloys. One chapter is reserved for ferrous alloys and another for nonferrous. A separate chapter is used to discuss the role played by cobalt in powder metallurgy, and another deals with the electroplating of cobalt.

In spite of the small size of the

(Continued on p. 252)



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Cobalt

(Starts on p. 248)

book, the information contained is thoroughly up to date, well documented, and ably presented. The high quality of the book is marred by a few errors and inconsistencies, of which only one will be mentioned: On p. 56 and 67, the melting point of cobalt is given as 1480° C., whereas the diagrams on p. 72, 94 and 96 show the melting point as 1490° C. Actually, the most probable value is 1495 ± 1° C., as determined at the National Bureau of Standards and published in 1947. LAURENCE S. FOSTER

Lithium*

ONE MAIN TYPE of raw material used in Germany during the war from which to extract lithium was the tailings from a tin ore containing 0.2 to 1.4% lithium. Concentrates therefrom were roasted with 30% potassium sulphate, the resulting lithium sulphate being treated with potassium carbonate, and the lithium carbonate converted to lithium chloride, which is then electrolyzed to obtain lithium. The other source was certain minerals containing lithium oxide, which are soaked in sulphuric acid and then roasted with aluminum sulphate at 1375° F. The product is dissolved in water, and lithium carbonate and chloride obtained as above.

Lithium chloride was electrolyzed in refractory-lined steel cells (18-in. cubes), in which were three graphite anodes and a steel cathode; the electrolyte consisted of 52% lithium chloride and 48% potassium chloride. With a current of 8 to 9 volts and 850 to 900 amperes, and a current efficiency of 85 to 90%, 10 lb. of lithium was obtained per cell per 24 hr., the electrolyte being maintained at 775° F. Power consumption was 140 kw-hr. per pound of lithium.

The main metallurgical applications of lithium were *(a)* for degassing and deoxidizing high-conductivity copper and *(b)* for making alloying additions for lead bearings, which contain 0.04% of lithium.

*From Report No. 25, British Intelligence Surveys, "The Nonferrous Metal Industry in Germany, 1939-1945", procurable for 90¢ from British Information Services, 30 Rockefeller Plaza, New York City 20.

Carbon-Beryllium Steels*

THE AUTHOR studied the influence of beryllium on carbon steels of five carbon contents. Compositions of the 27 steels investigated are listed in Table I. All these steels could be shaped under the forging hammer; the forgeability of steels with 0.5 to 0.9% C and 0.7 to 1.4% Be was similar to that of high-carbon high-chromium steel (2.0% C, 13% Cr).

Table I — Compositions of Beryllium Steels

C	Mn	Si	Be
Steels With 0.05% Carbon			
0.05	0.35	0.18	0.00
0.05	0.40	0.22	0.20
0.05	0.33	0.14	0.42
0.05	0.42	0.23	0.88
0.05	0.45	0.23	1.16
0.05	0.44	0.27	1.66
Steels With 0.2% Carbon			
0.24	0.41	0.26	0.00
0.25	0.38	0.21	0.18
0.19	0.38	0.28	0.38
0.19	0.38	0.32	0.63
0.24	0.52	0.53	0.82
0.21	0.51	0.45	1.42
Steels With 0.4% Carbon			
0.41	0.30	0.26	0.00
0.36	0.43	0.23	0.09
0.41	0.46	0.35	0.32
0.40	0.41	0.35	0.70
0.41	0.42	0.51	0.93
0.43	0.51	0.23	1.73
Steels With 0.55% Carbon			
0.54	0.44	0.18	0.00
0.54	0.47	0.26	0.43
0.53	0.43	0.26	0.74
0.56	0.51	0.31	1.44
Steels With 0.9% Carbon			
0.80	0.35	0.14	0.00
0.96	0.21	0.16	0.11
0.95	0.20	0.21	0.21
0.90	0.19	0.20	0.78
0.96	0.19	0.23	1.30

In general, the Ac_1 temperature is increased by beryllium, and the Ar_1 temperature is nearly independent of the beryllium content. For the determination of a structural diagram, microstructures of all the steels were examined after cooling in the furnace and in still air. The diagram has three fields: ferrite, ferrite + cementite, and ferrite + cementite + beryllium-bearing carbide. The beryllium-bearing carbide dissolves in austenite between 1740 and 1830° F.

The steels with 0.4 to 0.9% C

*Abstracted from a paper by W. Aichholzer in *Berg- und Hüttenmännische Monatshefte*, Vol. 93, June 1948, p. 100-114.

and 0.8 to 1.7% Be show a eutectic, containing the beryllium-bearing carbide; the eutectic melts at about 2000° F.

For studying the $\alpha \rightleftarrows \gamma$ transformation, the microstructures of all steels were examined after water quenching from temperatures between 1380 and 2000° F. Steels low in carbon and high in beryllium did not transform; they were ferritic at all temperatures.

The ferritic beryllium steels showed the usual strong increase in fracture grain size after heating to high temperatures. The fracture appearance of the pearlitic steels depends on the content of beryllium-bearing carbide. Thus, low-carbon low-beryllium steels that contain no special carbide behave like unalloyed steels, whereas undissolved beryllium-bearing carbide in the microstructure may inhibit grain growth up to 2000° F.

Beryllium increases the hardness of the as-forged and normalized steels. As shown in Table II, the increase is particularly striking

Table II — Hardness, As Forged and Normalized

Composition		Brinell Hardness	
C	Be	Forged	Normalized
Steels With 0.05% Carbon			
0.05	0.00	116	116
0.05	0.20	143	143
0.05	0.42	188	188
0.05	0.88	231	231
0.05	1.16	255	255
0.05	1.66	275	275
Steels With 0.2% Carbon			
0.24	0.00	163	156
0.25	0.18	207	228
0.19	0.38	228	269
0.19	0.63	286	286
0.24	0.82	321	302
0.21	1.42	364	340
Steels With 0.4% Carbon			
0.41	0.00	170	170
0.36	0.09	187	187
0.41	0.32	255	241
0.40	0.70	340	311
0.41	0.93	364	321
0.43	1.73	321	269
Steels With 0.55% Carbon			
0.54	0.00	196	207
0.54	0.43	302	286
0.53	0.74	340	302
0.56	1.44	340	293
Steels With 0.9% Carbon			
0.80	0.00	241	229
0.96	0.11	286	321
0.95	0.21	321	293
0.90	0.78	340	285
0.96	1.30	364	262

Beryllium Steels

in the low-carbon beryllium steels.

Confirming previous data of others, the author found that iron-beryllium alloys nearly free from carbon can harden by precipitation, but the reaction seems to be very slow. The beryllium steels are more resistant to softening than carbon steels (Fig. 1). Beryllium decreases the elongation, reduction in area and impact strength.

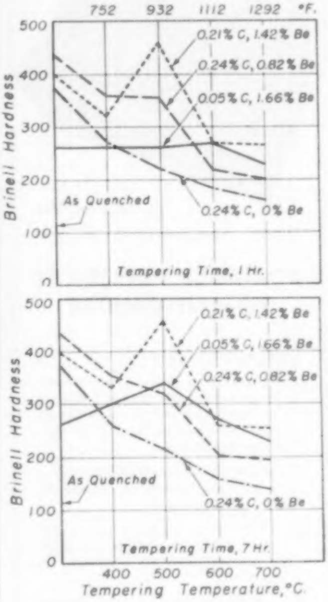


Fig. 1 — Temperability of Beryllium Steels Water Quenched From 1920° F.

Beryllium steels of high carbon content were investigated for magnetic characteristics. (O. von Auwers has previously observed that beryllium steels of low carbon content are unsuitable for transformer steel because hysteresis loss increases with beryllium content.) Steels with 0.9% C and beryllium content up to 1% have an increasing coercive force and residual induction, but above 1% Be these properties decrease.

Some of the steels were tested for resistance to scaling, to see whether the high affinity of beryllium for oxygen might make the steels suitable for commercial use at high temperature. For beryllium contents of 1.0 to 1.5%, scaling resistance was "good" up to 1200° F.

A steel with 0.05% C and 1.66%

Beryllium Steels

Be was corrosion tested in tap water, 10% nitric acid, 5% sulphuric acid and 1% hydrochloric acid at room temperature. The steel was very much attacked by all these reagents.

The author concluded that, even without considering the price of beryllium, there is no reason to use beryllium steels because all the improvements in properties can be obtained with alloying elements that are more easily controlled. However, it may be worthwhile to study the creep strength of structural steels containing beryllium, and the suitability of beryllium steels for hot work tools, on account of the stability on tempering. The effect of beryllium in steels alloyed with other elements should be investigated.

OTTO MIRT

Titanium*

THE USUAL SOURCE of titanium in wartime Germany was ilmenite ore. It was digested in sulphuric acid and the iron crystallized out and centrifuged. One novel process was carried out on a pilot-plant basis. Briquettes of ilmenite, coke (or coal), and sodium hydroxide (mixed in the proportion of 100 to 20 to 25, respectively) were charged into a small rotary furnace (35 in. inside diameter, 10 ft. long) and fused at 2400 to 2550° F. The products were carbon-rich iron and a slag of sodium titanate, from which titanium oxide is extracted.

Titanium metal is obtained by *(a)* reduction of titanium tetrachloride with sodium, *(b)* thermal decomposition of titanium tetrabromide, or *(c)* the reduction of titanium oxide with calcium hydride. The first and the last are the most widely used.

Sodium reduction is carried out at 1475° F. in vacuum-tight steel crucibles of approximately 20-in. diameter, each holding 33 lb. of sodium chloride, and 33 lb. of potassium chloride, titanium tetrachloride gas being passed through the charge. The calcium hydride process uses a molybdenum-wound tube furnace, 2 in. square by 6½

*From Report No. 25, British Intelligence Surveys, "The Nonferrous Metal Industry in Germany, 1939-1945", procurable for 90¢ from British Information Services, 30 Rockefeller Plaza, New York City 20.

Titanium

ft. long; reduction is by metallic calcium at 1300 to 1475° F. in a hydrogen atmosphere.

Titanium crystals, obtained as above, are further purified, and sintered after pressing into the desired shapes, or melted by the atomic hydrogen arc and cast into ingots. Titanium metal and titanium-rich alloys were hot worked at 1500 to 1650° F.

Main applications of titanium products reported are enamel fluxes, dielectrics and other components for the radio and electronic industries, titanium carbide for carbide tools, welding fluxes, heat resistant alloys, and armor plate.

Small Gas Turbine*

A SMALL GAS TURBINE for industrial use has been under test in England since late 1945, its construction having been preceded by developmental studies in details started two years previously. Constructed during a time when heat resisting alloys were very scarce, it represents what can be expected under minimum conditions of size and temperature. Apparently the greatest difficulty is in providing proper entrance and exit passages for the air or gas at compressor, combustion chamber and turbine so that uniform flow may result.

In a representative test run, air was heated to 520° F. by turbine exhaust before entering the compressor. The latter is an 8-stage axial flow compressor; the air leaves at about 1.34 atmospheres pressure and (in this test) at 810° F. temperature. After passing through another heat interchanger it was delivered to the combustion chamber at 1075° F. Gas outlet from combustion chamber was 1510° F., and from the turbine was 1150° F. Working under these conditions the turbine generated 1460 hp. gross, of which the compressor absorbed 1122 hp.; about 50 hp. was lost in bearing friction, and 300 hp. was left for useful work. This amounts to 15.6% of the calorific power of the fuel.

Compressor blades and vanes are of rolled duralumin, upset at

*Summary of "The Design and Operation of the Parsons Experimental Gas Turbine", by A. T. Bowden and J. L. Jefferson, *The Engineer*, Oct. 14 and 21, 1949, p. 442 and 472.

Small Gas Turbine

the root, and highly polished on leading and trailing surfaces. They are very short (about an inch), and have axial clearance of 0.006 in.

The combustion chamber is about 3 ft. 3 in. dia. by 7 ft. long; a mild steel tube. For about half its length it has a liner of 18-8 stainless steel, separated from the outer casing by ½-in. cooling space, through which supplementary combustion air flows. At the head end is a flame cone of "Nimonic" (75% Ni, 21% Cr, 2.5% Ti) at whose apex is the burner. As inferred above, direct flame impingement will ruin any part of this structure in short order.

The turbine is multistage with stainless iron blading (possibly influenced by the builder's experience with steam turbine construction). Hence the low-temperature operation — in the neighborhood of 1050° F. for continuous service. The radial clearance of 0.030 in. has been well maintained during four years of intermittent operation. One serious difficulty (not experienced when using gas for fuel) comes from ash. With oil fuel containing as little as 0.044% ash, accretions gather on the casing and rotor blades so rapidly as to stall the machine within 48 hr. No permanent damage to the metal surfaces has been noted.

Metal-Oxide Parts for Turbine Blades*

CERAMICS (refractory oxides) and metals are now being combined to make turbine blades. This promises to increase the permissible temperature, and thus the efficiency, at which gas turbines for aircraft and other applications can operate. Ceramic materials have been widely used for duct linings and stationary parts of gas turbines, but for use in moving parts they are too brittle and subject to cracking with quick temperature changes. Research on these materials is still at a preliminary stage, but the early test data are encouraging.

In the gas turbine, the turbine rotor is driven by the exhaust blast from the burning fuel, and the blades are subject to extremely high temperatures, as well as to a corrosive atmosphere and the stress of

*From *Industrial Bulletin* of Arthur D. Little, Inc., Nov. 1949.

Metal-Oxide Parts

whirling at thousands of revolutions per minute. Present metal alloys for turbine blades limit temperatures to about 1500° F., which gives the engine a thermal efficiency of about 24%. A rise to 1800° F. would mean an engine efficiency of about 28%. The new materials, if successful in other respects, would permit operating temperatures of at least 2000° F.

In the jet engine for aircraft, the same exhaust which propels the aircraft also drives a turbine which sucks air into the combustion chamber. Although a rise in operating temperature beyond 1500° F. would not improve the jet engine's ratio of fuel input to power output above about 14% efficiency, there would be an increase in the absolute thrust obtained.

German ceramists experimented with mixtures of aluminum oxide and powdered iron; an extensive research program in this country has substantiated their meager results and has yielded much new information. Standard powder metallury techniques may be used in fabrication. The metal and ceramic grains are milled together to the desired size, and are frequently held by a temporary binder, such as wax. The pieces are then pressed in molds at a pressure of 10,000 to 100,000 psi. The wax is melted or burned out at a relatively low temperature, and the final firing is in the temperature range between 2500 and 3000° F. This firing takes place in a carefully controlled atmosphere (argon, helium, nitrogen, hydrogen, or sometimes water vapor) or in a vacuum, which helps the particles of metal and ceramic to fuse to a solid structure. [Traces of zirconium metal also "wet" both metal and nonmetal particles, facilitating the bond.] In the resulting combination the metal binds together the oxide grains. Apparently the resistance of the metal to thermal shock is transmitted to the brittle ceramic material, while the resistance to high temperatures which is characteristic of the ceramic is imparted to the metal.

Other interesting techniques which have been tried are evaporating a mixture of the two powders onto a metal surface under vacuum, flame spraying a molten combination onto a metal core, to lay down a thin coating of mixed oxide and metal [or covering the surface of a refractory metal part with an easily oxidizable metal which later forms

Metal-Oxide Parts

a refractory oxide]. Impregnation of a piece of porous ceramic with molten metal has also been successful. The possible metal-ceramic combinations are almost endless. The ceramics include borides, carbides, oxides, spinels, or combinations of these, while the metal could be almost any of the heat resistant metals or alloys. Only a few combinations have been tested thus far.*

To date only a few actual turbines have been tested using such blades as described above. The more recent of these tests are especially promising for the extreme conditions which may be encountered in future aircraft turbines.

When and if the technique is perfected, applications outside the gas turbine field will probably be found. A possible one is in shear knives for hot metal, which require high abrasion resistance at elevated temperatures. Valve seats which can be ground smooth and have good compressive strength are perhaps another use.

Brazing Metals to Nonmetals†

A SERIES of experiments attempted to determine the generality of a method described in 1947 by R. J. Bondley of General Electric Research Laboratory, wherein he prepared metal-ceramic seals by using a brazing alloy and a flux of titanium hydride in an atmosphere of highly purified hydrogen.

The equipment consisted of a closed tube furnace containing the samples to be brazed, a surrounding coil for high frequency heating currents, and methods for producing the correct atmosphere (or vacuum). Zirconium hydride shows somewhat superior wetting and bonding qualities to those of titanium hydride. Good results were also obtained with the hydrides of tantalum and columbium. These hydrides are easily obtainable.

*Nomenclature is quite various. Some experimenters call the products "cermets"; others "ceramels", "ceramals" or "metamics".

†Abstract of "Metal to Nonmetallic Brazing", by C. S. Pearsall and P. K. Zingeser, Technical Report No. 104, Research Laboratory of Electronics, Massachusetts Institute of Technology.

Brazing Metals to Nonmetals

Other hydrides, no doubt, have desirable properties and would be adaptable to this type of brazing.

The method has been used in brazing a wide variety of materials, such as diamonds, sapphires, carbides, various ceramics, refractory oxides, glass, quartz, stainless steel and chromium-iron alloys. The active metals used in this brazing technique have the interesting property of wetting both metals and nonmetallic materials equally well, producing exceptionally strong bonds which often exceed the strength of the nonmetallic materials.

The general procedure involves coating the surface to be brazed with thin films of the hydride. A water paste or a nitrocellulose-solution binder seems to work equally well. A piece of suitable solder is then placed in contact with the hydride-coated surface. The combination is heated to approximately 1000° C. (1825° F.) or to a temperature at which the solder flows freely in a vacuum of 10^{-4} mm. of mercury or better, or in an atmosphere of pure hydrogen or pure inert gas. When the proper temperature is reached, the brazing alloy will melt and flow over the hydride-coated surface in a manner somewhat similar to the way it does in the brazing of metals.

Copper-silver eutectic solder and pure silver are both very satisfactory brazing materials. Pure aluminum also gives excellent results as a brazing metal, particularly with the use of columbium and tantalum hydride.

Certain experiments indicated that hydrogen was not necessary to the brazing operation, so alloys of silver and zirconium were prepared by vacuum melting. An alloy (or mixture) containing 15% zirconium and 85% silver will wet and bond ceramics, diamond, sapphire, or carbides, in much the same manner as the hydride. Equally good results were obtained by placing fragments of zirconium metal and silver wire on the surface to be brazed and heating to the flow point; an alloy was formed; it wet and bonded the nonmetallic materials. Alloys of aluminum and zirconium and of aluminum-silver-zirconium show good wetting and bonding properties.

Alloys of these active metals titanium, zirconium, columbium or

Brazing

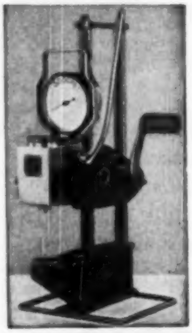
tantalum (Ag-Zr in particular) seem to offer considerable promise in brazing the stainless steels. The metal surfaces need no special treatment other than ordinary solvent degreasing. Thin oxide films do not inhibit the brazing process, since the alloy readily wets and bonds oxides. The silver-zirconium alloy also brazes molybdenum parts with success.

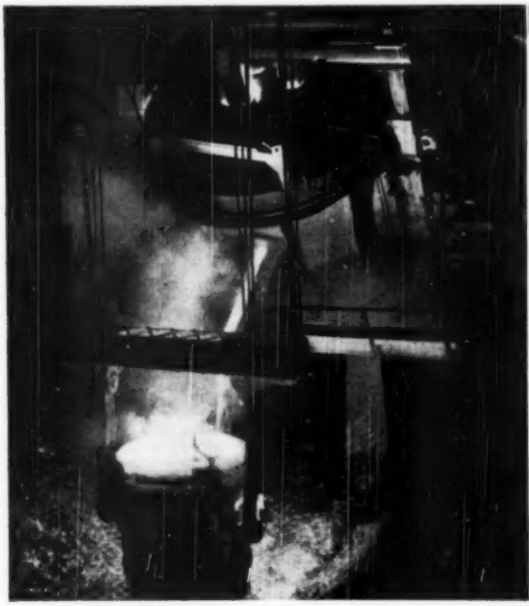
If the brazing operation is carried out with titanium hydride in a hydrogen atmosphere, careful purification of the gas is necessary, to the point where it will not tarnish a bright wire of stainless steel heated to 1800° F. Clean stainless steel can be brazed with either copper or copper-silver eutectic solder in this highly purified hydrogen. When ordinary tank hydrogen is used, the stainless steel rapidly oxidizes and completely inhibits the flow of solder on the surfaces.

When lamp argon containing 0.4% nitrogen is used, a slight discoloration may occur on the surface of the brazing alloy. This seems to have no detrimental effect on the brazing operation when zirconium and titanium hydrides are used. Zirconium, on the other hand, exhibited good wetting and bonding qualities in highly purified nitrogen, yielding clean, bright surfaces. Zirconium brazing, in addition, was carried out successfully in an atmosphere of commercial dry tank nitrogen, although a certain amount of tarnish was produced on the brazed surface. The bonds produced with zirconium in tank nitrogen, although not so clean as those produced in vacuum, seem, however, to be equally sound.

This general technique seems to lend itself to the preparation of highly refractory bodies such as those used in gas turbines, jet engines, and rockets; cemented carbide tools, heating elements and crucibles; various low-temperature ceramic bodies. Furthermore, metal-ceramic bodies could be prepared with a wide range of thermal expansions to match metals and glasses by adjusting the percentages of metal and ceramic in the composite material.

[EDITOR'S FOOTNOTE — There is some suggestion that volatile "active" metals or fumes of their compounds may be toxic. Consequently, work such as the above should be hooded and most thoroughly ventilated to the outside.]





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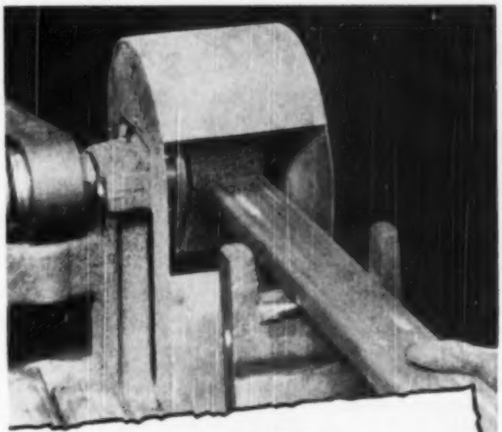

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